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NATIONAL IMPERATIVES FOR EARTH SCIENCE RESEARCH

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE, AERONAUTICS, AND RELATED SCIENCES

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED TENTH CONGRESS

FIRST SESSION

MARCH 7, 2007

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NATIONAL IMPERATIVES FOR EARTH SCIENCE RESEARCH

WEDNESDAY, MARCH 7, 2007

U.S. SENATE,
SUBCOMMITTEE ON SPACE, AERONAUTICS, AND RELATED SCIENCES,
COMMITTEE ON COMMERCE, SCIENCE AND TRANSPORTATION,
Washington, DC.

The Subcommittee met, pursuant to notice, at 2:38 p.m. in room SR–253, Russell Senate Office Building. Hon. Bill Nelson, Chairman of the Subcommittee, presiding.

OPENING STATEMENT OF HON. BILL NELSON, U.S. SENATOR FROM FLORIDA

Senator NELSON. Good afternoon, and thank you all for coming. This is not a hearing on global warming, because the jury is already in and the conclusions have been overwhelming. There's almost near-unanimity of the world's leading scientists that the climate is changing, and we are responsible.

It is especially sensitive for my state for the obvious reasons of being a peninsula with more coastline than any other state in the continental United States.

So, today we're going to examine the more specific issue of whether you scientists have the tools that you need to monitor our fragile planet, and to study how what we're doing as humans is affecting it.

This is simply a time in which we cannot afford any mistakes. For more than 40 years, NASA has developed satellites to study this planet, and they have ever-increasing accuracy. Go back to the 1960's TIROS satellites, those fuzzy views have now turned to the high-quality views that we have today. Space has clearly turned out to be the best vantage point from which we can study and observe this planet.

We depend on these instruments, certainly to forecast our weather. If anybody ever doubts the utility of those instruments, just wait until you have an inbound hurricane, and you're absolutely glued to either the website of NOAA, the Weather Channel, or the local channel, that's giving you these accurate satellite views, along with NOAA's predictions from the National Hurricane Center.

We depend on these instruments to forecast the weather, to predict and respond to natural disasters, and to study our climate and the Earth's ecosystems. They even help us measure the effects of land-use, deforestation, and pollution. NASA's history is filled with successful missions, like Landsat, and the Earth Observing System.

Just a week ago, during our recess, I took off to Latin America visiting with several heads of state on a mission to build our relationships in that region of the world and throughout the Western Hemisphere.

But one of the things that I wanted to do en route from having seen the President of Ecuador, going to see the President of Peru, was to go to the rainforest. There wasn't any sense of me going to the rainforest in Brazil, because they were all off at Carnival. But, they were available in the rainforest in the east of the Andes in Peru. I wanted to see for myself the destruction of the rainforest, in this case the uplands of the rainforest. On the sides of those mountains there was destruction, not so much for logging, but for the growing of coca and other plants, and legitimate crops.

I shared with them that I became interested in deforestation 21 years ago, when I looked out the window of a spacecraft, coming across South America when, with the naked eye, I could see the destruction of the rainforest, because of the color contrast 203 miles away on the surface of the Earth below. In the same window of the spacecraft, I could look to the east, and see the result of the destruction of the rainforest. At the mouth of the Amazon the waters of the Atlantic were discolored for hundreds of miles out in the Atlantic from the additional silt.

I want to understand that. I want to understand also, and this Committee wants to understand, how you all can help us understand so much of this delicate, fragile, but extremely beautiful place we call home that is suspended out in the middle of nothing.

Today there is a reason for concern, for what my naked eye saw 21 years ago, and what my naked eye saw a week and a half ago on the sides of those lower Eastern Andes. We've tried to adjust to all of this, and we have a next-generation weather and earth satellite system, NPOESS—it's in trouble.

The project is billions of dollars over budget, it's years behind schedule, and the key climate science instruments have been thrown overboard to keep the program alive. And while the President's 2008 budget request does include a miniscule increase, spending on Earth Science peaked in 2000, and has since decreased by 25 percent.

Likewise, the number of Earth Science missions and instruments peaked earlier this decade, and is now in a slow decline. The President's request this year is a billion and a half for these Earth Science projects, and you all would like them to be $2 billion. I want to hear from you, the Committee wants to hear from you.

This is not so much a problem of misplaced priorities, but rather, NASA is being asked to do too much with too little. And in this tough budget environment, it's tough to get these colleagues, it's tough to get them here to a hearing, it's tough to get them to join in supporting the program recommended by the Decadal Survey. Not at the expense of the other priorities, but by giving NASA the resources it needs to accomplish all of its vital missions.

So, I want to welcome Dr. Freilich, Dr. Moore, Dr. Brown, Ms. Colleton. We're going to do something a little bit different. I'm going to take all of your prepared texts, they will be a part of the record. We're just going to have a conversation. When some of the other Senators come, I'll just stop and I'll let them jump right in.

What we want to do is to get the maximum benefit of your thinking on what we should do.

[The prepared statements of the witnesses follow:]

PREPARED STATEMENT OF BERRIEN MOORE III, PH.D., DISTINGUISHED PROFESSOR AND DIRECTOR, INSTITUTE FOR THE STUDY OF EARTH, OCEANS, AND SPACE, UNIVERSITY OF NEW HAMPSHIRE; CO-CHAIR, COMMITTEE ON EARTH SCIENCE AND APPLICATIONS FROM SPACE, NATIONAL RESEARCH COUNCIL, THE NATIONAL ACADEMIES

Mr. Chairman, Ranking Minority Member, and members of the Committee: thank you for inviting me here to testify today. My name is Berrien Moore, and I am a professor of systems research at the University of New Hampshire and Director of the Institute for the Study of Earth, Oceans, and Space. I appear today in my capacity as co-chair of the National Research Council (NRC)'s Committee on Earth Science and Applications from Space: A Community Assessment and Strategy for the Future.

The National Research Council is the unit of the National Academies that is responsible for organizing independent advisory studies for the Federal Government on science and technology. In response to requests from NASA, NOAA, and the USGS, the NRC has recently completed a "Decadal Survey" of Earth Science and Applications from space. ("Decadal surveys" are the 10-year prioritized roadmaps that the NRC has done for 40 years for the astronomers; this is the first time it is being done for Earth Science and Applications from space.) Among the key tasks in the charge to the Decadal Survey committee were to:

- Develop a consensus of the top-level scientific questions that should provide the focus for Earth and environmental observations in the period 2005–2020; and
- Develop a prioritized list of recommended space programs, missions, and supporting activities to address these questions.

The NRC survey committee has prepared an extensive report in response to this charge, which I am pleased to be able to summarize here today. Over 100 leaders in the Earth Science community participated on the survey steering committee or its seven study panels. It is noteworthy that this was the first Earth Science Decadal Survey, and the Committee and panel members did an excellent job in fulfilling the charge and establishing a consensus—a task many previously considered impossible. A copy of the full report has also been provided for your use.

The Committee's vision is encapsulated in the following declaration, first stated in the Committee's April 2005 Interim Report: [1]

> "Understanding the complex, changing planet on which we live, how it supports life, and how human activities affect its ability to do so in the future is one of the greatest intellectual challenges facing humanity. It is also one of the most important challenges for society as it seeks to achieve prosperity, health, and sustainability."

As detailed in the Committee's final report, and as we were profoundly reminded by the latest report from the International Panel on Climate Change (IPCC), the world faces significant and profound environmental challenges: shortages of clean and accessible freshwater, degradation of terrestrial and aquatic ecosystems, increases in soil erosion, changes in the chemistry of the atmosphere, declines in fisheries, and above all the rapid pace of substantial changes in climate. These changes are not isolated; they interact with each other and with natural variability in complex ways that cascade through the environment across local, regional, and global scales. Addressing these societal challenges requires that we confront key scientific questions related to ice sheets and sea level change, large-scale and persistent shifts in precipitation and water availability, transcontinental air pollution, shifts in ecosystem structure and function in response to climate change, impacts of climate change on human health, and occurrence of extreme events, such as hurricanes, floods and droughts, heat waves, earthquakes, and volcanic eruptions.

Yet at a time when the need has never been greater, we are faced with an Earth observation program that will dramatically diminish in capability over the next 5–10 years.

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[1] NRC, *Earth Science and Applications from Space: Urgent Needs and Opportunities to Serve the Nation*, The National Academies Press, Washington, D.C., 2005. Also available online at *http://www.nap.edu/catalog/11281.html*.

The Interim Report described how satellite observations have been critical to scientific efforts to understand the Earth as a system of connected components, including the land, oceans, atmosphere, biosphere, and solid-Earth. It also gave examples of how these observations have served the nation, helping to save lives and protect property, strengthening national security, and contributing to the growth of our economy[2] through provision of timely environmental information. The Interim Report documented that NASA had canceled, scaled back, or delayed at least six planned missions (Table 1), including a Landsat continuity mission. This led to the main finding in the Interim Report: "this system of environmental satellites is at risk of collapse."

Table 1.—Canceled, Descoped, or Delayed Earth Observation Missions

[From the April 2005 Pre-Publication of the Interim Report of the Decadal Survey on Earth Science and Applications from Space]

Mission	Measurement	Societal benefit	Status
Global Precipitation Measurement (GPM)	Precipitation	Reduced vulnerability to floods and droughts; improved capability to manage water resources in arid regions; improved forecasts of hurricanes.	Delayed
Atmospheric Soundings from Geostationary Orbit (GIFTS—Geostationary Imaging Fourier Transform Spectrometer)	Temperature and water vapor	Protection of life and property through improved weather forecasts and severe storm warnings.	Canceled
Ocean Vector Winds (active scatterometer follow-on to QuikSCAT)	Wind speed and direction near the ocean surface	Improved severe weather warnings to ships at sea; improved crop planning and yields through better predictions of El Niño.	Canceled
Landsat Data Continuity—bridge mission (to fill gap between Landsat–7 and NPOESS)	Land cover	Monitoring of deforestation; identification of mineral resources; tracking of the conversion of agricultural land to other uses.	Canceled
Glory	Optical properties of aerosols; solar irradiance	Improved scientific understanding of factors that force climate change.	Canceled
Wide Swath Ocean Altimeter (on the Ocean Surface Topography Mission, OSTM)	Sea level in two dimensions	Monitoring of coastal currents, eddies, and tides, all of which affect fisheries, navigation, and ocean climate.	Instrument canceled—descope of an enhanced OSTM

Since the publication of the Interim Report, the Hydros and Deep Space Climate Observatory missions were canceled; the flagship Global Precipitation Mission was delayed for another two and a half years; significant cuts were made to NASA's Research and Analysis program; the NPOESS Preparatory Project mission was delayed for a year and a half; a key atmospheric profiling sensor planned for the next generation of NOAA geostationary satellites was canceled; and cost overruns led to the NPOESS program undergoing a "Nunn-McCurdy" review. The recertified NPOESS program delays the first launch by 3 years, eliminates 2 of the planned 6 spacecraft, and de-manifests or de-scopes a number of instruments, with particular consequences for measurement of the forcing and feedbacks that need to be measured to understand the magnitude, pace, and consequences of global and regional climate change.

It is against this backdrop that I discuss the present report.

The Decadal Survey presents a vision for the Earth Science program; an analysis of the existing Earth observing system and recommendations to help restore its capabilities; an assessment of and recommendations for new observations and missions needed for the next decade; an examination of and recommendations concerning effective application of those observations; and an analysis of how best to sustain that observation and applications system. *A critical element of the study's*

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[2] It has been estimated that one third of the $10 trillion U.S. economy is weather-sensitive or environment-sensitive (NRC, *Satellite Observations of the Earth's Environment: Accelerating the Transition of Research to Operations,* The National Academies Press, Washington, D.C., 2003).

vision is its emphasis on the need to place the benefits to society that can be provided by an effective Earth observation system on a par with scientific advancement.

The integrated suite of space missions and supporting and complementary activities that are described in our report will support the development of numerous applications of high importance to society. The expected benefits of the fully-implemented program include:

- *Human Health*

  More reliable forecasts of infectious and vector-borne disease outbreaks for disease control and response.
- *Earthquake Early Warning*

  Identification of active faults and prediction of the likelihood of earthquakes to enable effective investment in structural improvements, inform land-use decisions, and provide early warning of impending earthquakes.
- *Weather Prediction*

  Longer-term, more reliable weather forecasts.
- *Sea Level Rise*

  Climate predictions based on better understanding of ocean temperature and ice sheet volume changes and feedback to enable effective coastal community planning.
- *Climate Prediction*

  Robust estimates of primary climate forcings for improved climate forecasts, including local predictions of the effects of climate change; determination in time and space of sources and sinks of carbon dioxide.
- *Freshwater Availability*

  More accurate and longer-term precipitation and drought forecasts to improve water resource management.
- *Ecosystem Services*

  More reliable land-use, agricultural, and ocean productivity forecasts to improve planting and harvesting schedules and fisheries management.
- *Air Quality*

  More reliable air quality forecasts to enable effective urban pollution management.
- *Extreme Storm Warnings*

  Longer-term, more reliable storm track forecasts and intensification predictions to enable effective evacuation planning.

I will now turn to a brief discussion of the budgetary implications of our recommendations.

The President's FY08 budget request for NASA Earth Science is a mixture of some good news and bad news. The primary bit of good news is the small bottom line increases for 2008 and 2009. These increases address the needs of currently planned missions already in development, the completion of which is consistent with the Decadal Survey's baseline set of assumptions.

Unfortunately, the out-year budgets reveal fundamental flaws in the budget and NASA's Earth Science plans—the budgets are totally inadequate to accomplish the Decadal Survey's recommendations. In 2010, the Earth Science budget begins to decline again and reaches a 20-year low, in real terms, in 2012. This decline reflects that the 2008 budget contains no provision for new missions, nor does it allow us to address the significant challenges facing our planet. These disturbing broad budgetary trends are captured in Figure 1.

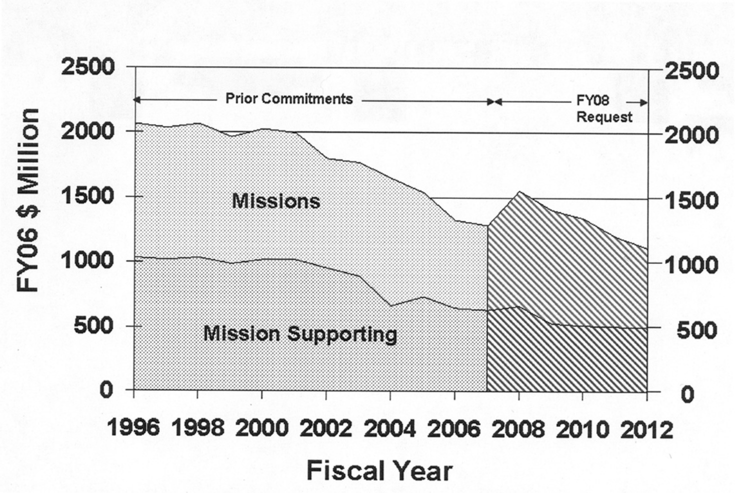


Figure 1: The NASA Earth Science Budget in constant FY06 dollars (normalized for full-cost accounting across entire timescale; assumes 3 percent/year inflation from 2006 to 2012). Mission supporting activities include Earth Science Research, Applied Sciences, Education and Outreach, and Earth Science Technology.

Before turning to NOAA, I want to emphasize that the problems in the out-years appear to be due entirely to the lack of adequate resources. In fact, at a NASA town hall meeting that followed the release of our report on January 15, 2007 at the 2007 annual meeting of the American Meteorological Society, the head of NASA's Earth Science program, who appears today with me as a witness, stated that the recommendations in our report provided the roadmap for the Earth Science program we *should* have.

The NOAA NESDIS budget picture is also a mixture of some good and bad news. In this case, the budget takes a small downturn in FY08, followed by significant growth in FY09–FY10, before turning down again in FY11 (Figure 2). It remains to be seen whether this ~$200 M/year growth in FY09 and FY10 can enable restoration of some of the lost capabilities to NPOESS and GOES–R. There appears to be no budgetary wedge for new starts. Finally, for a variety of reasons, the NOAA NESDIS budget is far from transparent, especially in the out-years.

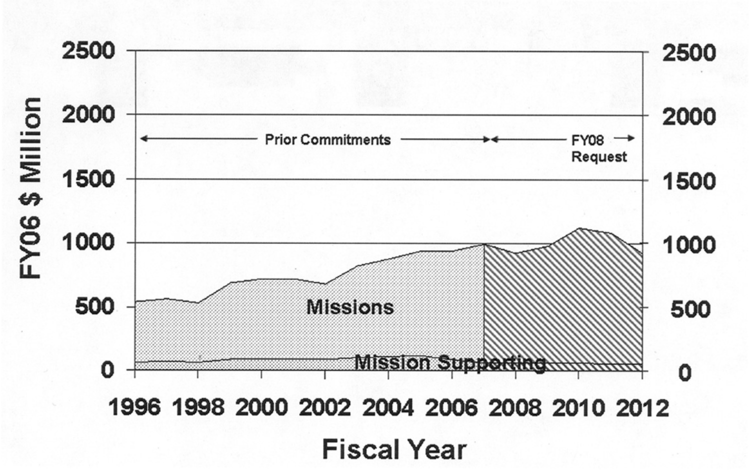
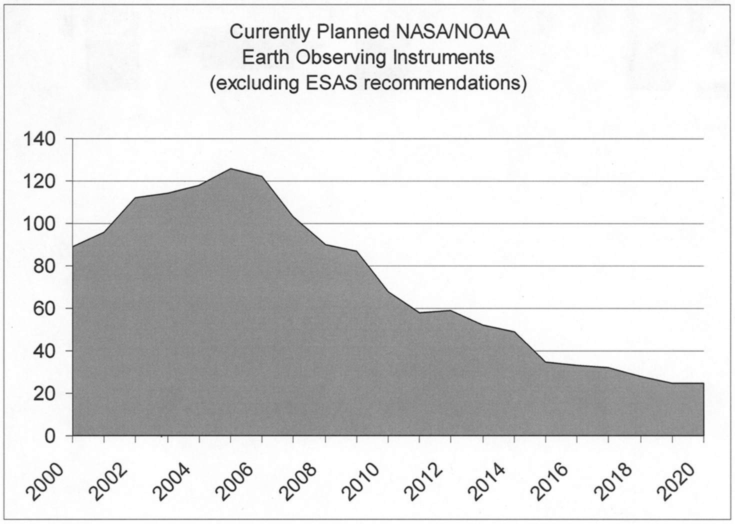


Figure 2: The NOAA NESDIS Budget in constant 2006 dollars (assumes 3 percent/year inflation from 2006–2012). Mission supporting activities include NOAA's

Data Centers and Information Services, Data System Enhancements, Data Exploitation, and Information Services, and Facilities and Critical Infrastructure Improvements.

As detailed in our report, between 2006 and the end of the decade, the number of operating U.S. missions will decrease dramatically and the number of operating sensors and instruments on NASA spacecraft, most of which are well past their nominal lifetimes, may decrease by some 35 percent. If present trends continue, reductions of some 50 percent are possible by 2015.



Were this to pass, we would have chosen, in effect, to partially blind ourselves at a time of increasing need to monitor, predict, and develop responses to numerous global environmental challenges. Vital climate records, such as the measurement of solar irradiance and the Earth's response, will be placed in jeopardy or lost. Measurements of aerosols, ozone profiles, sea surface height, sources and sinks of important greenhouse gases, patterns of air and coastal pollution, and even winds in the atmosphere are among the numerous critical measurements that are at risk or simply will not occur if we follow the path of the President 2008 budget and the proposed out-year run out.

Taking this path, we will also forgo the economic benefits that would have come, for example, from better management of energy and water, and improved weather predictions.[3] Without action on the report's recommendations, a decades-long improvements in the skill in which we make weather forecasts will stall, or even reverse; this may be accompanied by diminished capacity to forecast severe weather events and manage disaster response and relief efforts. The nation's capabilities to forecast space weather will also be at risk, with impacts on commercial aviation and space technology.[4]

The world is facing significant environmental challenges: shortages of clean and accessible freshwater, degradation of terrestrial and aquatic ecosystems, increases in soil erosion, changes in the chemistry of the atmosphere, declines in fisheries, and the likelihood of significant changes in climate. These changes are occurring over and above the stresses imposed by the natural variability of a dynamic planet, as well as the effects of past and existing patterns of conflict, poverty, disease, and malnutrition. Further, these changes interact with each other and with natural variability in complex ways that cascade through the environment across local, regional, and global scales. To cope responsibly with these challenges requires information about our planet; it requires us to expand our scientific basis for foreseeing potential changes and patterns, and this science is dependent upon expanded space-based observation. The needed new missions are set forth in the Decadal Survey; these missions need to be implemented in the coming decade.

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[3] In a typical hurricane season, NOAA's forecasts, warnings, and the associated emergency responses result in a $3 billion savings. Two-thirds of this savings, $2 billion, is attributed to the reduction in hurricane-related deaths, and one-third of this savings, $1 billion, is attributed to a reduction in property-related damage because of preparedness actions. Advances in satellite information, data assimilation techniques, and more powerful computers to run more sophisticated numerical models, have lead to more accurate weather forecasts and warnings. Today, NOAA's five-day hurricane forecasts, which utilize satellite data, are as accurate as its three-day forecasts were 10 years ago. The additional advanced notice has a significant positive effect on many sectors of our economy. See statement and references therein of Edward Morris, Director, Office of Space Commercialization, NOAA, Hearing on Space and U.S. National Power, Committee on Armed Services Subcommittee on Strategic Forces, U.S. House of Representatives, June 21, 2006. Available at: *http://www.legislative.noaa.gov/Testimony/morris062106.pdf.*

[4] *Ibid.*

I would like to thank the Committee for inviting me to testify, and I would be delighted to answer any questions.

PREPARED STATEMENT OF OTIS B. BROWN, PH.D., DEAN, ROSENSTIEL SCHOOL OF MARINE AND ATMOSPHERIC SCIENCE, UNIVERSITY OF MIAMI; MEMBER, COMMITTEE ON EARTH SCIENCE AND APPLICATIONS FROM SPACE, NATIONAL RESEARCH COUNCIL, THE NATIONAL ACADEMIES

Mr. Chairman, Ranking Minority Member, and members of the Committee: thank you for inviting me here to testify today. My name is Otis Brown, and I am Dean of the Rosenstiel School of Marine and Atmospheric Science, University of Miami. I am also a member of the National Research Council's Committee on Earth Science and Applications from Space.

As dean of the Rosenstiel School, I have first-hand experience how satellite observations provide real-world results. Following Hurricane Katrina, imagery from our Center for Southeastern Tropical Advanced Remote Sensing (CSTARS) assisted relief and recovery efforts in New Orleans, tracking to see when and where flood waters had receded to increase the effectiveness of rescue efforts. Also pertinent to the environmental challenges presenting themselves in the Gulf states, we employed satellite imagery that identifies the rate of subsidence in the Mississippi Delta and New Orleans—equally invaluable information when making decisions about the reality and requirements of rebuilding in this area and long-term environmental challenges. This same imagery is what we use to monitor water levels in the Everglades and outbreaks of red tide. And, uses for satellite data only continue to grow as we learn to "see" phenomena like changes in sea surface temperature, sea level, and the size of polar ice caps. I cannot emphasize enough how vital satellite imagery has become to earth observation and consequently our ability to predict, plan, prepare, and respond.

I've been asked to discuss my perspectives on the "National Imperatives for Earth Sciences Research." This topic includes areas relevant to many parts of the Federal Government. My testimony today focuses on the roles of NASA and NOAA. It also addresses some resource and coordination issues for these two agencies.

As you may know I have been part of the team that recently produced a decadal plan for Earth observations from space, which provides a prioritized roadmap. Our vision is captured in the following declaration:

> Understanding the complex, changing planet on which we live, how it supports life, and how human activities affect its ability to do so in the future is one of the greatest intellectual challenges facing humanity. It is also one of the most important challenges for society as it seeks to achieve prosperity, health, and sustainability.

As detailed in the NRC report, and further emphasized by the latest report of the Intergovernmental Panel on Climate Change (IPCC), our planet is faced with a number of significant scientific and societal challenges and their impacts on key parts of our society, economy, and health. The two-year study contained in the NRC report delineates how NASA's Earth Science budget has declined 30 percent since 2000, with more funding reductions planned as its priority missions of manned trips to Mars and a station on the Moon take further hold. The National Ocean and Atmospheric Administration (NOAA) likewise faces funding challenges with its National Polar-orbiting Operational Environmental Satellite System (NPOESS)—now 3 years behind schedule and $3 billion over budget. Additionally, many of the satellite system's advanced weather and climate instruments have been dropped to address cost and schedule challenges. Meanwhile, current satellites continue to age, and many of us foresee major shortcomings in satellite observations by the end of this decade that will undo much of the progress we have made in Earth observation and weather prediction.

So, at a time when our need for understanding the Earth system and the need for Earth observations have never been greater, we are faced with declining investments in Earth Science, and, an Earth observation program that will significantly diminish in capability over the next decade.

The first question the National Research Council committee had to address was the national capabilities for Earth observations. We were troubled by the answer.

We found that the current investment strategies had led to a system at risk of collapse. That assessment was based on the observed decline in funding for Earth observation missions in NASA and the consequent cancellation, downsizing, and delay of a number of critical missions and instruments in both agencies. Since the interim report, matters have only worsened, with further cancellations, descopings and delays of NOAA and NASA satellite plans. This will result in an overall degradation of the network of Earth observing satellites.

There are many potential consequences. Some examples are:

- Weather forecasts and warnings may become less accurate, putting more people at risk and diminishing the proven economic value of accurate forecasts—this is particularly important to this country since we must cope with many forms of extreme weather, be it in the form of hurricanes, tornadoes, drought, floods or winter storms.
- Climate variability and the rate of change need to be better quantified. Earth is warming because of a small imbalance between incoming solar radiation and outgoing radiation from Earth. Without the recommended measurements, we will not be able to quantify how this net energy imbalance is changing, or when or if the planet will stop warming.
- Climate models have improved steadily over the years, but are far from perfect and must be improved if we are to intelligently cope with climate change. Satellites provide unique observations of the Earth system and validate and improve these models.
- Sea level is rising and glaciers and ice-fields around the world are melting, but we just don't know how fast these are occurring. Without continuing quantitative observations provided via satellites, we can't know how these rates change or the implications for coastal communities.
- Satellite observations could well be pivotal in resolving a controversy about whether the frequency and intensity of hurricanes are increasing; observations of the atmosphere and oceans are essential.
- The limited signals of cataclysmic activity come through vigilant observation. That means the risk of missing early detection of earthquakes, tsunamis, and volcanic eruptions will increase.
- The bottom line is: Earth Science is based fundamentally on observations. While it is impossible to predict what scientific advances will not occur without the observations, or what surprises we will miss, we can be sure the rate of scientific progress will be greatly slowed—perhaps even undone to some degree. Without a doubt, it takes us backward rather than forwards.

Significant advances in hurricane forecasting over the past three decades have come from orbiting satellites that take timely, high-resolution pictures and provide improved estimates of surface wind over the ocean. The satellite images are all over the TV for the public to view, but scientists, dissect them further. From sea level, sea surface temperatures and winds to red tide outbreaks and oil spills, satellite observations afford us a better, informed view of our Earth.

The climate debate has been driven by debate over model capabilities and the lack of long-term critical observations relevant to climate. Many of the capabilities to make such observations exist in the research domain, but have not been transitioned into an operational setting. Our NRC report noted the difficulties in transferring NASA and NOAA research into operational use. That is because there is currently no process to include the necessary scientific input, resources and exploitation capabilities to either facilitate or to define this transition. Thus, we are seeing the winding down of the NASA Earth Observing System and its broad Earth observing capabilities and information delivery systems, with no apparent way for our Nation to harvest the fruits of this multi-billion dollar investment, or, to continue prototype research systems with proven operational value. The follow-on NOAA system, NPOESS, is late and more than likely will not overlap the NASA systems, and, most of the climate-related capabilities are not in its baseline. Put succinctly, much needed long-term time-series of Earth processes required for decisions in this changing world will be lost. This is due to the lack of a functional relationship between research (NASA) and operations (NOAA) for Earth observing systems, and, a lack of resources in NOAA to address all of its Earth observing requirements.

The challenge in Earth Sciences is that the breadth of study is so large that it's difficult to develop a set of priorities across disciplines. This is the first ever report to provide an integrated set of national priorities for Earth observing from space. It's equally difficult for anyone to imagine how it affects them individually. Often times, it seems we speak in a foreign language about solar irradiance, vector sea surface winds, limb sounding of ozone profiles and water vapor soundings from geostationary and polar orbits—perhaps this is not the clearest way for the public to understand how humans have become dependent on tools that reside in outer space.

What is important to understand about the plan our committee recommended is that its financial requirements are *not* astronomical. In fact, implementing all of the recommendations requires only that we bring the program up to funding levels comparable to the year 2000. The plan we recommend calls for undertaking 17 new NASA and NOAA missions in the period 2008–2020, as well as restoring some of the capabilities lost on NPOESS and GOES, and revitalizing a few delayed NASA missions like GPM and Landsat. Our recommendations for NASA can be implemented in an extremely cost-effective manner. The Committee understood the financial constraints and therefore had to find missions capable of tackling several scientific questions simultaneously. The result is that we reduced the number of possible new missions from more than 100 down to 17 broad-ranging, high-value, multipurpose missions. But to accomplish this, NASA's Earth Science budget must be restored to year 2000 funding levels. We think this is very reasonable given the obvious societal needs and benefits.

The truth of the matter is that this field of science is inextricably linked to our daily life and that of future generations. Climate variability and natural disasters are taking a significant toll on our economy, our environment, and our well being. And, that is why we must sustain the Earth observations that underpin national preparedness and response. Implementing these missions will not only greatly reduce the risk of natural disasters of all kinds to the people of our country and the world, they will also support more efficient management of natural resources including water, energy, fisheries, and ecosystems, and support the economy. Thus, the cost of the program is repaid many times over.

The observing system we envision is affordable and will help establish a firm, sustainable foundation for Earth Science and real societal benefits through the year 2020 and beyond.

Thank you for the opportunity to appear before you today. I would be pleased to answer any questions that you may have.

PREPARED STATEMENT OF DR. MICHAEL H. FREILICH, DIRECTOR, EARTH SCIENCE DIVISION, SCIENCE MISSION DIRECTORATE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to appear today to discuss the President's FY 2008 budget request for NASA's Earth Science program. I welcome the chance to discuss the important area of Earth Science, especially in light of the recently released National Research Council's Earth Science Decadal Survey.

NASA's FY 2008 budget request includes $1.5 billion for the study of planet Earth from space. This represents an increase of $27.7 million over the FY 2007 budget request, and will fund a wide-ranging and balanced program of activities, including: developing, launching, and operating Earth-observing space missions; competitively selected research and analysis science investigations conducted by NASA and non-NASA researchers; Applied Science projects that help other Federal and regional agencies and organizations to efficiently use products from NASA Earth research to advance their missions; ongoing technology development efforts to enable the missions of the future; and, education and public outreach programs to make our knowledge of the Earth accessible to the world. NASA's budget request supports a balanced program, allocating over 30 percent of NASA's request for the Science Mission Directorate and within the Science Mission Directorate, allocating 27 percent of funding for Earth Science.

NASA remains by far the largest single contributor to the interagency U.S. Climate Change Science Program (CCSP). Much of the science community's present state of knowledge about global change—including many of the measurements and a significant fraction of the analyses which serve as the foundation for the recent report of the Intergovernmental Panel on Climate Change (IPCC)—is derived from NASA's Earth Science program. To list just a few examples, using data from Earth observing satellites NASA-supported researchers are: monitoring ice cover and ice sheet motions in the Arctic and the Antarctic; quantifying the short-term and long-term changes to the Earth's protective shield of stratospheric ozone, including the positive impacts of the Montreal protocols; discovering robust relationships between increasing upper ocean temperature and decreasing primary production from the phytoplankton that form the base of the oceans' food chain; and, using a fleet of satellites flying in formation (the "A-Train") to make unique, global, near-simultaneous measurements of aerosols, clouds, temperature and relative humidity profiles, and radiative fluxes.

Our improved understanding of Earth System processes leads to improvements in sophisticated weather and climate models, which in turn—when initialized using the satellite data—can be used to predict natural and human-caused changes in the Earth's environment over time scales of hours to years.

Importantly, near-real-time measurements from NASA research missions (including the Tropical Rainfall Mapping Mission, QuikSCAT, the Atmospheric Infrared Sounder instrument on the Aqua mission, and others) are used routinely by the National Oceanic Administration (NOAA) and other U.S. and international agencies to improve weather forecasting. Similarly, high quality measurements obtained by operational weather satellites provide essential context for the scientific analyses of the NASA research mission data.

As of today, NASA is operating 14 Earth observing missions. Five more missions are quite far advanced in their development, and will be launched in 2008 and 2009. Of these, the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) and the Ocean Surface Topography Mission (OSTM) will continue critical Earth System and climate measurements that were initiated by the Earth Observing System (for NPP) and the TOPEX/Poseidon and Jason-1 missions (for OSTM). The Glory mission will fly an instrument to extend our measurements of total solar irradiance, as well as an instrument that will provide unique, first-ever measurements of properties of atmospheric aerosols. The Orbiting Carbon Observatory (OCO) and the Aquarius mission will make new, first-of-a-kind global measurements of atmospheric carbon dioxide concentrations and ocean surface salinity—both parameters of known importance to the study of climate change.

The FY 2008 budget request also funds the reconstituted Landsat Data Continuity Mission (LDCM) for launch in 2011, and the Global Precipitation Measurement Mission (GPM) for launch of its Core spacecraft not later than 2013, followed a year later by launch of the NASA GPM Constellation spacecraft. Extending the pioneering rain measurements initiated with the joint U.S.-Japanese Tropical Rainfall Mapping Mission, and providing a calibration standard for several other rain-measuring instruments orbited by others, the GPM mission will provide us with accurate, *global* rain measurements much more frequently than currently possible. Knowledge of accurate rainfall rates and atmospheric water quantities is essential for the study of the Earth's hydrologic cycle and its sensitivity to climate change. In addition, the GPM measurements will be used by operational weather prediction agencies around the globe to improve weather forecasts and severe storm predictions.

Even as we are acquiring and analyzing measurements today, we are planning the satellites, field experiments, scientific investigations, and Earth System models of the future. The recently released Earth Science Decadal Survey provides, for the first time, a scientifically based, community consensus statement of the top priority future Earth System Science problems to be addressed, and it suggests a sequence of notional missions whose measurements could contribute to advancing our understanding of the Earth and its environment.

We welcome the Decadal Survey—indeed, we asked for it. NASA, along with NOAA and the U.S. Geological Survey (USGS), requested and funded the National Research Council (NRC) to conduct this first Decadal Survey in Earth Science. We formally made the request in the fall of 2003 and the study began in earnest in 2004. The massive undertaking was only completed this January. We are grateful for all of the efforts of the Co-Chairs and NRC staff, the members of the Decadal Survey Executive Committee, and the literally hundreds of Earth Science researchers who volunteered their time and their ideas. Their success in creating scientific consensus across the broad and diverse Earth Science community is a substantial achievement.

The science priorities identified by the Decadal Survey will be our primary guide as we design and select Earth observing missions to be flown in the next 10–15 years. In the space sciences, NASA has a long history of guidance by NRC Decadal Surveys. Indeed, even in the Earth Sciences where this is the first Decadal Survey, the President's FY 2008 budget request for NASA was guided by recommendations included in the interim report issued by the Decadal Survey committee in 2005. The FY 2008 budget request includes funding and predictable launch dates for the Landsat Data Continuity Mission, the Glory aerosol and solar irradiance mission, and the Global Precipitation Mission, all of which figured strongly in the interim report.

Unfortunately, the Decadal Survey arrived too late for its specific recommendations to influence the FY 2008 budget process, but its scientific priorities will be used in development of the FY 2009 and subsequent budget requests. NASA's FY 2008 budget request also includes funding for an additional, unspecified, competed flight mission, which will launch sometime around 2014. We will be guided by the Decadal Survey as we choose the scientific focus and instrument complement for this mission, starting no earlier than 2008.

In addition to its science priorities and the notional mission set, the Decadal Survey provides several recommendations relevant to the design and implementation of the Earth Science flight program. Survey recommendations in the areas of international collaboration and technology investment deserve particular consideration.

We all recognize that a constellation of missions and many simultaneous measurements—such as those obtained by the A-Train spacecraft described above—are needed to understand the interactions between Earth system processes. No agency or nation can afford to develop and fly all necessary missions single handedly.

The Decadal Survey emphatically recommends international collaboration, to maximize humankind's benefits from our net investment in Earth Science, and to avoid unnecessary duplication. To this end, we have already begun discussions with our 5 closest international space agency partners: the Canadian, European, French, Japanese, and German space agencies. We have begun planning substantive bilateral meetings to be held this spring, to identify and refine areas of common interest and complementary expertise. We are also actively engaged—indeed NASA and the U.S. are leaders—in international coordination bodies such as the Committee on Earth Observation Satellites (CEOS) and the international Group on Earth Observations (GEO). As with our present OSTM, Aquarius, and GPM missions, we anticipate substantial joint projects with international partners as we construct missions to address the Decadal Survey's science questions.

Science-driven technology investment is one of the keys to the design and implementation of any future mission set. It is essential to have the technology developed and tested in a relevant environment prior to the approval of any mission. This helps to avoid cost overruns that occur when problems arise with a new technology late in the mission development cycle. To foster advanced technologies for Earth Science, NASA's strategy is two pronged as recommended by the Decadal Survey, with both focused technology and core technology elements.

Where we know the missions we want to implement and what new technologies are required on a certain schedule, we make focused investments to assure technologies are available when we issue competitive solicitations for mission formulation and development. This is done through the highly successful Instrument Incubator Program, funded under the Earth Science Technology Office, which matures instrument technologies for future measurements.

The second prong addresses the seed corn or "core technologies," for advanced Earth observing missions of the future. Where we know that certain classes of technologies are needed for the types of measurements we would like to make in the future, or are simply convinced that investment in certain sensor or detector technology areas will yield fruit, we will issue open, competitive solicitations for the best ideas. Examples include advanced component development (which allows scientists and technologists to take an idea from the concept to the bench top demonstration stage), laser risk reduction (which has developed fundamental lidar technologies applicable to multiple NASA missions), and advanced information systems technology development (which provides advanced operations technologies which aid in reducing future mission costs).

The Decadal Survey, the U.S. Climate Change Science Program, and NASA's own planning in Earth Science all assume the presence of an operational system of environmental monitoring satellites that can make climate-quality measurements. The Nation needs such a system. That is why NASA is a member of the NPOESS governing body, and why NASA entered into a partnership with the NPOESS Integrated Program Office to develop the NPOESS Preparatory Project (NPP). NPP is designed both to continue essential measurements from NASA's Earth Observing System satellites as well as provide a demonstration of instruments to be flown on NPOESS.

The Nunn-McCurdy-certified NPOESS program, as you are aware, focuses NPOESS on its weather mission and deletes many of the capabilities previously planned for climate science. It is thus important to recognize that the NRC's work is not yet done. As the Decadal Survey Committee was finalizing its notional mission set and sequence, the full impact of the removal of the climate sensors from the NPOESS program was just coming to light. In discussion with the NRC, NASA and NOAA have structured a follow-on activity wherein a subset of the Decadal Survey Committee, augmented by others they may deem necessary, would hold a workshop and provide input on how the agencies might mitigate the impact of the changes to NPOESS. We expect that the NRC workshop will take place no later than early summer, in time to provide recommendations useful for helping to determine the FY09 budget.

NASA is proceeding with a mission roadmapping activity to determine the focus and content of our specific future Earth observing missions. The roadmap will integrate the scientific recommendations and priority/sequence of the Decadal Survey, the joint and ongoing NASA–NOAA examinations of the NPOESS Nunn-McCurdy changes, and the contributions of our international partners. Through a series of concept studies conducted at NASA centers (some actually begun in anticipation of the Decadal Survey mission suggestions), we are carefully examining the Decadal Survey's notional missions. The studies are assessing the technological readiness, system engineering challenges, and expected costs (including support for scientific validation and analysis of the mission data) of each notional missions. These concept studies are accessing the full capability of the NASA mission design and costing apparatus, to complement the estimates assigned by the NRC. As the roadmap evolves, community involvement will be assured through regular interactions with the Earth Science Subcommittee of the NASA Advisory Council, as well as existing discipline- and science-focus theme working groups which regularly inform our plans and examine our progress within the NASA Earth Science Division.

The roadmapping process includes the anticipated update later this year to the NASA Earth Science Plan. Indeed when the Congress asked the Agency for a Science Plan in the NASA Authorization Act of 2005 (P.L. 109–155), you recognized that the Decadal Survey would not be available in time to influence the Earth Science portion of that Plan. Therefore, NASA was asked to describe how it might revise that Plan based on the Earth Science Decadal Survey. The roadmapping activity and the Science Plan will address that question.

While the scope and specificity of the roadmap clearly must exceed that of the Decadal Survey and must accommodate issues of programmatic balance and national needs, it is definitively *not* our intention to redo the Decadal Survey or to change the scientific priorities that it identified.

As with decadal surveys in other parts of the Science Mission Directorate portfolio, this Decadal Survey is only the starting point for planning. However, planning in Earth Science is even more complex than in other divisions, given the web of partnerships and users of Earth Science data, and its societal impact. Considering the long time horizon in the NRC's report, it will require several budget cycles to implement the program that we will derive from the Decadal Survey's near- and mid-term recommended mission sets. Nevertheless, our planning process starts with the consensus scientific priorities articulated for us by the NRC. So I will close by re-iterating my gratitude to the decadal survey committee Co-chairs and members for their excellent work. NASA's commitment to Earth Science research is commensurate with theirs.

Table 1.—NASA Earth Science Missions Currently in Development

NPOESS Preparatory Project (2009) Strategic mission; Systematic measurement	Ensures continuity of several key climate measurements between the Earth Observing System and NPOESS. Implementation of the NPOESS Presidential Decision Directive of 1994. Joint mission with the NPOESS Integrated Program Office.
Landsat Data Continuity Mission (2011) Strategic mission; Systematic measurement	Ensures continuity of long-term global land cover change data. Post-LDCM land imagery acquisition by an operational agency is planned. Joint mission with USGS.
Ocean Surface Topography Mission (2008) Strategic mission; Systematic measurement	Ensures continuity of ocean altimetry data; planned as part of a transition to operational agencies. Joint mission with NOAA, CNES & EUMETSAT.
Glory (2008) Strategic mission; Initializes a systematic measurement	Addresses high priority objective of the U.S. Climate Change Science Program. Measure global aerosols & liquid cloud properties and solar radiation. Mandated by the Presidential Climate Change Research Initiative of 2001.
Orbiting Carbon Observatory (2008) Competed mission; Earth System Science Pathfinder	Nearing completion of development. First global measurement of CO_2 from space; small Earth Science mission.

Table 1.—NASA Earth Science Missions Currently in Development—Continued

Aquarius (2009) Competed mission; Earth System Science Pathfinder	In advanced stage of development. First global measurement of sea surface salinity from space; small Earth Science mission. Joint mission with Argentina.
Global Precipitation Measurement (2013) Strategic mission—Initializes a systematic measurement	Recommended by 2005 interim report of decadal survey committee; extend spatial coverage to global and temporal coverage to every 3 hours with constellation.
Earth System Science Pathfinder; TBD (2014) Competed mission	*Focus and relative priority to be determined using decadal survey;* solicitation no earlier than 2008 for 2014 launch.

PREPARED STATEMENT OF NANCY COLLETON, PRESIDENT, INSTITUTE FOR GLOBAL ENVIRONMENTAL STRATEGIES; EXECUTIVE DIRECTOR, ALLIANCE FOR EARTH OBSERVATIONS

Introduction

Chairman Nelson, Ranking Member Hutchison, members of the Committee, special guests, ladies and gentlemen, I am Nancy Colleton, president of the Institute for Global Environmental Strategies, a non-profit, 501(c)3 organization. Our efforts are devoted to furthering knowledge of the Earth system and promoting the value and use of the technology tools that help us better understand our changing planet. The Institute's efforts include everything from developing resources for K–12 science education and teacher professional development, to facilitating international cooperative activities in Earth Science and applications.

I am here today representing one of our major initiatives, the Alliance for Earth Observations—an informal confederation of organizations devoted to promoting Earth observations for social and economic benefit. The Alliance has been a strong advocate of the importance of engaging the private sector (industry, academia, and non-governmental organizations) in the planning of Earth observation systems, primarily the U.S. Integrated Earth Observation System (IEOS) and the multinational Global Earth Observation System of Systems (GEOSS).

The Alliance membership is diverse and includes stakeholders such as system developers, data providers, geospatial technology firms, university-based research institutes, and a non-governmental organization that focuses on science applications for conservation. Since our effort began in December 2003, we have implemented an aggressive outreach effort to numerous business sectors (*e.g.,* clean technologies, energy, agriculture, public health) to raise awareness of the importance of Earth observations. *Attachment A* includes a listing of the Alliance members. An Alliance *Public Policy Statement on the Decadal Survey for Earth Observations* is included in *Attachment B*.

We are here today to examine one of the most critical tools of Earth Science: satellite observations. Whether we realize it or not, we all work in the field of Earth Science and benefit from satellite observations. Whether you are a policymaker, an investor, a farmer, a fisherman, or a truck driver, the Earth is changing and it is influencing our work, our decisions, our recreation, our resources, our economy, and our future. I am honored to participate in this important hearing, National Imperatives for Earth Science Research.

Response to the Report

The purpose of today's hearing is to discuss the recent National Research Council report, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*. I thank Drs. Berrien Moore and Rick Anthes on the leadership that they have provided as co-chairs of this study. I congratulate them and the other members of the Decadal Survey Committee on this exceptional report. As we all know, the quality and breadth of reports such as this don't just happen; they require a very dedicated and concerted effort.

Quoting from the report, "the United States' extraordinary foundation of global observations is at great risk. Between 2006 and the end of the decade, the number of operating missions will decrease dramatically and the number of operating sensors and instruments on NASA spacecraft, most of which are well past their lifetimes, will decrease by 50 percent." As my colleague, Governor Jim Geringer (former Governor of Wyoming) pointed out in his testimony on this topic on February 13th to the House Science and Technology Committee, "That means a fifty percent reduction in today's already inadequate space-based information systems. . . . It is difficult to maintain your vision from a crumbling vantage point."

I offer four primary observations to this Senate Committee for your consideration and deliberation:

- The fact that the Decadal Survey Committee's vision for a decadal program in Earth observations went beyond fundamental science to consider "increased applications to serve the Nation and people of the world" is a significant and much-needed shift in approach to the U.S. program.
- The U.S. should buildupon our space-based Earth observation programs and move forward with the U.S. IEOS—incorporating space, aircraft, and *in situ* instruments, and the requisite analytical capabilities.
- Clear leadership is essential to resolve the issues and attain the goals identified in the Decadal Survey.
- The time to act is now.

Increased Applications to Serve the Nation and the World

This year, we will celebrate the 20th anniversary of *Our Common Future,* the groundbreaking report of the World Commission on Environment and Development led by former Norwegian Prime Minister Gro Harlem Brundtland. The report begins as follows:

> In the middle of the 20th century, we saw our planet from space for the first time. Historians may eventually find that this vision had a greater impact on thought than did the Copernican revolution of the 16th century, which upset the human self-image by revealing that the Earth is not the centre of the universe. From space, we see a small and fragile ball dominated not by human activity and edifice but by a pattern of clouds, oceans, greenery, and soils. Humanity's inability to fit its doings into that pattern is changing planetary systems, fundamentally. Many such changes are accompanied by life-threatening hazards. This new reality, from which there is not escape, must be recognized—and managed.
>
> Fortunately, this new reality coincides with more positive developments new to this century. We can move information and goods faster around the globe than ever before; we can produce more food and more goods with less investment and resources; our technology and science gives us at least the potential to look deeper into and better understand natural systems. From space, we can see and study the Earth as an organism whose health depends on the health of all its parts. We have the power to reconcile human affairs with natural laws and to thrive in the process. In this our cultural and spiritual heritages can reinforce our economic interests and survival imperatives.

It is insightful that, even in 1987, world leaders recognized that not only would space technology help us understand the Earth, but that it could also be a unique tool to better manage our planet for social benefit and economic interests.

But, it is disappointing that despite this powerful text published 20 years ago, we are gathered here today for a hearing examining the decline in U.S. space-based Earth observing capabilities.

Since that time, our U.S. systems have focused primarily on answering scientific questions, with applications of this data and information as a secondary objective. And, although we have seen significant growth and impact of operational programs at the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Geological Survey (USGS), science requirements are still what drive the development of our space-based systems.

The fact that the Decadal Survey Committee's vision for an Earth observations decadal program went beyond fundamental science to consider "increased applications to serve the nations and people of the world" is a significant step and much-needed shift in approach to the U.S. program.

We must recognize that the technologies that we are discussing today are the same technologies that:

- Enabled us to track and forecast Hurricane Katrina;
- Enabled us to discover and visualize the ozone hole;
- Allowed us to detect the impacts of the Indian Ocean tsunami and to determine the true extent of the devastation it caused;
- Continue to identify receding Arctic glaciers; and
- Were used by the Intergovernmental Panel on Climate Change in their studies.

Just last week, we again witnessed the benefit of Earth observation satellite technology to our nation:

- NOAA weather satellites provided critical lead time for the Southeast tornadoes (in some cases 12–55 minutes); and
- NASA's MODIS (Moderate Resolution Imaging Spectroradiometer) on the Aqua satellite enabled us to view the extent of dust storms caused by high winds over Northern Texas *(Dallas Morning News* and *Houston Chronicle* reported that downed power lines left some 37,000 homes and businesses without power. Grass fires were also reported).

The benefits of space-based data will not end this week or next. In fact, the need for this type of information and the responsibility of the United States as a world leader to maintain and share this important capability will only increase with the stress of climate change.

In a January 12, 2007, speech to the World Affairs Council, Lord Levene, Chairman of Lloyd's, provided a global insurer's perspective on catastrophe trends and climate change. He stated, "We cannot risk being in denial on catastrophe trends. We can expect to see U.S. mega-catastrophes with $100 billion insured losses soon. We urgently need a radical rethink of public policy, and to build the facts into our future planning." He added, "The insurance industry will continue to play a vital role as enabler and rebuilder of the U.S. economy." U.S. satellite assets and the products provided as a result of space-based observations are critical to ensuring that insurance and other sectors have accurate and timely information.

Not only should the United States strive to answer key scientific questions, but it should respond to the needs of a broad, non-scientific user community, which relies increasingly upon operational missions by NOAA. By this I mean how can we ensure that our national research program and technologies are meeting the needs of policymakers, state and local water managers, energy executives, and emerging areas such as the carbon finance market? This will involve additional study and possible correction of our current research-to-operations processes based on new engagement with the diverse and emerging user communities to provide more input to our national planning for new systems.

Move forward with IEOS

Former Wyoming Governor Jim Geringer, who testified to the Senate Commerce Committee in April 2006 on drought and the need for integrated information, also wrote in November 2006 to the Office of Management and Budget to express the need to fund IEOS, the U.S. contribution to the multinational Global Earth Observation System of Systems (GEOSS). He wrote:

> Sir Francis Bacon coined the phrase "Knowledge is power." Today it's not about power but about empowerment as our country faces many challenges. More than ever we need better data-driven decisions. The first essential part is observation, the gathering of data. But we need more than data. Accurate and timely observations become information that leads to knowledge that enables decisions. We must reduce uncertainty to enable better risk management for businesses as well as protect citizens and save lives and property.

In the December 2006–January 2007 issue of *Environmental Finance* Magazine, Vijay Gudivaka reported that "Companies are working overtime to get a better understanding of their environmental impacts." The article discusses the need for more effective environmental data management and how companies are being challenged to develop data bases to better assess environmental, health, and safety information. Gudivaka writes, "Whatever system is being used to collect and distribute environmental information needs to keep meeting the requirements of the business—or it has to change."

Without an established information infrastructure that builds upon our space-based Earth observation programs, we face many questions currently: Are our current systems meeting the needs of our businesses? Are our current systems protecting our citizens and property? . . . maintaining U.S. competitiveness? . . . ensuring that public and private sector decisionmakers, have, and will in the future have the information they need to respond to challenges like climate change? The Decadal Survey highlights the need to do more. My work with numerous business, academic, and non-government leaders also reveals that our systems must be improved to meet the requirements of business.

Warren Isom, Senior Vice President, Willis Re Inc., and Board Member of the Weather Risk Management Association remarked at the Forum on Earth Observations last year, "The weather risk market—in fact the risk-management business in general—has a profoundly strong interest in serious, systematic attempts to improve, expand and intensify the capture of data relating to our planet."

The current U.S. system must change to combine and integrate the valuable and extensive information sources and tools across all Federal agencies. This would create the IEOS, new interoperable systems that enable an unprecedented picture of our world, with a better understanding of intended benefits.

The Alliance for Earth Observations believes that by embarking on the development of IEOS that the United States will:

- Give its *citizens* the single most important and comprehensive technology tool to monitor and respond to our changing world, thereby protecting lives and property;
- Give its *Federal leaders and managers* robust observational data and models that are fundamental to performance measurement, decision-making, and accelerating our understanding of environmental processes;
- Provide *U.S. industry* with the data needed to better manage risk and resources, make transportation decisions, create new business opportunities in environmental information products and services, and thereby impact long-term environmental sustainability;
- Enable our *country* to remain the world leader in energy development and management, agriculture productivity, marine transportation, public health and other areas;
- Support *the global community* by working in partnership with other countries to share and integrate important data and information; and
- Give *future generations* the knowledge and tools needed to leave a better world for each succeeding generation.

IEOS will leverage Earth Science and technology for the benefit of U.S. citizens and the world. In the area of climate change, IEOS would provide accurate and timely observations as the foundation for guiding U.S. climate change policy, ensuring our Nation is moving in the right direction and providing the basis for knowing whether our policies are making the intended positive impacts we expect. The National Integrated Drought Information System (NIDIS), which is a key component of IEOS, would provide a proactive solution for U.S. citizens, delivering the "business intelligence" needed to manage the risk of drought. Regarding energy security, observations are critical to both the supply and demand sides of energy. On the supply side, all sources of alternative and renewable energy are highly dependent on environmental data. These energy resources include hydropower, wind, ocean energy (tide, current, wave), biofuels, photovoltaics, and geothermal sources. On the demand side, environmental conditions largely determine the overall demand for power as well as the variability in demand. By funding the IEOS, the United States would provide a new level of service to the American people to prevent, mitigate or manage the effects of natural hazards through linked and interactive systems that provide the United States and the world with greater forecasting capability. Even in the area of public health, IEOS would lead to:

- Improved air quality forecasting;
- Improved and earlier recognition of harmful algal blooms;
- Earlier recognition of the need for beach closures; and
- A national water quality monitoring system that, for the first time, would integrate disparate water quality systems into one comprehensive system—a major step forward for the United States.

IEOS benefits can only be achieved through a common U.S. integrated information architecture. The benefits discussed in the previous paragraphs all depend on the development of a common observation and information system architecture for Earth observations. This architecture would facilitate information sharing between and among agencies as well as promulgate standards for terminology, data discovery, data access and transport, and service interfaces. This approach would enable our investment in environmental data, products and services to be leveraged by many communities of interest, generating value to both citizens and the economy through improved decisionmaking and incubation of a value-added market for environmental products and services. A robust and scalable architecture for an environmental enterprise would:

- Leverage federally funded activities in other data-rich domains;
- Enable communities of interest to easily and transparently access a variety of thematically diverse and geographically dispersed assets; and

- Enable any group or organization to easily connect their assets into the enterprise in an interoperable fashion without significant investment in information systems.

IEOS would also advance the Global Earth Observation System of Systems (GEOSS), which is now supported by more than 66 countries and 46 international organizations. This U.S.-initiated effort is intended to allow Federal interagency and multi-national coordination to assure that disparate environmental-related data systems here at home and abroad are interoperable and compatible. An effective IEOS effort should have clear designation of responsibilities, be enabled by a web-based system that allows rapid communication, funded across agency boundaries with a clear purpose. IEOS/GEOSS would improve the capabilities for today's decision-makers by providing new information products. That is not the case today. IEOS has neither been funded nor has program leadership been designated.

Clear Leadership Is Essential

Clear leadership is essential to resolve the issues and attain the goals identified in the Decadal Study. The report before you calls for increased funding to improve our current national Earth monitoring capability. Yes, funding is important but the essential missing element is leadership. Scientific assessment, increased budgets, improved technical capabilities, and coordinated public-private engagement need designated, consolidated leadership. Critical elements including satellite and aircraft sensors, *in situ* instruments such as stream gauges, and geospatial information systems, have been fragmented among our Federal agencies, always a secondary mission, never the priority responsibility.

Earth observation is not a priority mission for any designated agency at the cabinet level. Not within NASA, the Department of Commerce, the Department of the Interior nor any other Federal agency. The important technologies that enable us to measure climate change and identify and monitor the impacts to our environment, our lives and our livelihood are the sole responsibility of no one agency or person.

Who should be the lead agency or position for U.S. Earth observation capabilities? What is our national vision for Earth observations? How are requirements from the Federal operational sector such as NOAA, USGS, USDA and EPA reflected in our research and development programs within NASA and NSF? Are requirements from the private sector being addressed?

Without a designated lead, we will not see:

- These critical assets protected;
- A national Earth observations strategy that appropriately addresses climate change;
- The required investment for these programs appropriately reflected in agency plans and budgets;
- Our national investment fully leveraged for societal and economic benefit;
- The smooth transition from research to operations;
- Our land-observing capabilities elevated to the level of atmospheric and ocean observations;
- An improved engagement between government and the private sector (industry, Academia, and non-governmental organizations);
- The much-called-for integration of our national Earth observation systems; and
- The products needed to make the best decisions for our country and future generations.

As a first step, I support the report's recommendation that:

> The Office of Science and Technology Policy, in collaboration with the relevant agencies, and in consultation with the scientific community, should develop and implement a plan for achieving and sustaining global Earth observations. Then a single point of contact or program office at the Cabinet level should be established to assure complementary rather than duplicative or fragmented effort for all operational aspects of Earth observation and analysis.

I urge that the private sector—industry, academia, and non-governmental organizations—be consulted regarding an integrated plan for Earth observations.

Time To Act

As we are often reminded, time passes quickly.

In preparation for this hearing, I reviewed numerous reports, one of which is noted earlier in this testimony and is entitled, *Linking Remote Sensing Technology* *and Global Needs: A Strategic Vision*. It was a report to NASA on applications. Ironically, the vision outlined in this 1987 report was as follows:

> The vision for the future is an Applications Information System available to all users—whether a large government agency or small local firm—that will provide overall benefits for the public good and further economic interests of the United States.

What we knew 20 years ago, what the Brundtland Commission acknowledged in their groundbreaking report, and what we are reminded of today is that our nationally-funded Earth Science and operational technology programs are vital to our society and economy. If nothing else, I hope that the Decadal Survey will motivate you as policymakers and leaders to take action now—action to protect, leverage, and advance these assets so critical to protecting our nation, the world, and our future. Let us not 20 years from now simply acknowledge the words written by the Decadal Survey Committee, but rather be able to point to the Decadal Survey as a turning point for action and commitment to protect, further develop, and exploit these assets for benefit of the Nation and the world.

Attachment A

THE ALLIANCE FOR EARTH OBSERVATIONS

Atmospheric and Environmental Research, Inc. (AER)
Ball Aerospace & Technologies Corp.*
The Boeing Company*
Booz, Allen, Hamilton*
Caris
Center for Southeastern Tropical Advanced Remote Sensing (CSTARS), University of Miami
CIESIN at Columbia University
Computer Sciences Corporation (CSC)
EADS Space
ESRI*
Global Science & Technology, Inc. (GST)
Harris*
Lockheed Martin*
Mitretek Systems
NatureServe
L3 Communications – Maripro, Inc.
Northrop Grumman*
Raytheon*
Science Applications International Corporation (SAIC)*
Scripps Institution of Oceanography
Southeastern University Research Association (SURA)
Woods Hole Oceanographic Institution

*Executive Committee Members

The Alliance was formed in 2004 to facilitate participation by the private sector—industry, Academia, and nongovernmental organizations—in U.S. and international planning for Earth observations, especially as it relates to GEOSS. The Alliance for Earth Observations is an initiative of the nonprofit Institute for Global Environmental Strategies, a 501(c)3 nonprofit organization.

Attachment B

THE ALLIANCE FOR
EARTH OBSERVATIONS

Public Policy Statement on the Decadal Survey for Earth Observations by The Alliance for Earth Observations

The Alliance for Earth Observations commends the work started by the National Research Council Space Studies Board Committee on Earth Science and Applications from Space in its recently released report: *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond.* This important report sheds light on the declining Earth observation capabilities of the United States and lays out priorities for the next decade for Earth observations from space. This report offers the foundation of a roadmap to bring the U.S. Earth Observation capability in line with expectations for meeting the global change and climate policy challenges we see so frequently in the headlines. Science information is needed to inform policy, and the "Earth Science Decadal Survey" as this report is called, points us in the direction we need to advance our national capability into the 21st Century.

The members of the Alliance recognize the immense value to society—both in terms of economic benefits to our citizens and in meeting our responsibilities as stewards of our environment—of U.S. programs in space-based Earth observations. The Committee, capably led by Dr. Richard A. Anthes, President of the University Corporation for Atmospheric Research and Dr. Berrien Moore III, Professor and Director of the Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, was comprised of an outstanding team of subject matter experts. In their report, they have provided a very valuable prioritization of scientific questions that need to be addressed along with recommendations for the space-based missions that should be developed and launched to provide the data needed to address important societal issues—in the near, mid, and far term.

The Alliance recognizes the challenge in the current budget climate of augmenting funding for multiple agencies charged with executing the Nation's operational and research Earth observations programs. In the recently released President's Budget Request for Fiscal Year (FY) 2008, funding for satellite programs at the National Aeronautics & Space Administration (NASA), National Oceanographic & Atmospheric Administration (NOAA), and U.S. Geological Survey would not accommodate the recommendations of the report. The President's Budget, if enacted in FY–08, would enable NOAA to proceed with current acquisition plans for both the polar-orbiting and geostationary satellite programs, with their now-reduced instrument suites, and NASA to maintain momentum only on their current set of missions. The Alliance recognizes the importance of increasing U.S. Government funding to accomplish the recommendations in the report to advance our national Earth satellite programs. Funding would need to be implemented as top line budget increases, in order to not affect other important agency priorities.

The Alliance agrees with the Decadal Survey and its predecessor reports from the National Academy of Sciences that current NOAA, NASA, and USGS budgets and programs do not include the programmatic structure needed to manage the research, development, and flight testing of new instrument technologies, and subsequent transition to operational missions, necessary to continue to evolve U.S. operational Earth observation capacity. Thorough technology demonstrations could have provided the risk mitigation needed to curtail decisions to cancel critically needed climate monitoring, ocean imaging, and advanced atmospheric sounding instruments from the NPOESS and GOES–R programs. Future plans and decisions can benefit from the report's recommendations to invest in developing next generation technologies and systems to reduce cost and schedule risks to operational programs. Implementation of the report's recommendation would be timely in addressing this longstanding problem.

The Alliance for Earth Observations is a publicly and privately funded initiative of the Institute for Global Environmental Strategies to promote the understanding and use of land, air and sea observations for societal and economic benefit.

Senator NELSON. So, Dr. Moore, do you consider the 17 missions recommended in the survey an all-inclusive wish-list? Or do you consider it the minimum responsible complement of the measurement tools?

STATEMENT OF BERRIEN MOORE III, PH.D., DISTINGUISHED PROFESSOR AND DIRECTOR, INSTITUTE FOR THE STUDY OF EARTH, OCEANS, AND SPACE, UNIVERSITY OF NEW HAMPSHIRE; CO-CHAIR, COMMITTEE ON EARTH SCIENCE AND APPLICATIONS FROM SPACE, NATIONAL RESEARCH COUNCIL, THE NATIONAL ACADEMIES

Dr. MOORE. First of all, Senator thank you for inviting myself and my colleagues.

I think, given what this planet is faced with—and you have articulated that well this afternoon—I believe it is the minimal responsible recommendation that looks at the challenges facing the planet.

And it is not a wish list. We had a wish list—there were 110 wishes put forth, with a lot of enthusiasm. And we cut that with NASA receiving 15, NOAA receiving 3, and one shared jointly, making a total of 17.

I know it's expensive, but I believe there are ways that one can reach back to that restoration of $2 billion. It's certainly not going to be done in 1 year or 5 years, but there's a process that would be beneficial. I think it's a reasoned response to the challenges.

Senator NELSON. What would be the impact if only a fraction of those 17 were implemented?

Dr. MOORE. Well, that would depend upon which fraction.

For instance, let's suppose that we don't go ahead with Synthetic Aperture Radar that would give us the NSAR, the inframetric radar that gives us a much better understanding of earthquake potential. That's very valuable to this country, and very valuable to the planet.

If we don't move forward with the recommended Aerosol Mission—we won't be capable of making aerosol observations when forests are burned, releasing tremendous pollutant loads of aerosols. Some of those aerosols actually lead to global cooling, many lead to global warming. So the only way to arrive at a balance is through observations of the aerosols.

We recommended a CO_2 mission that would be active, that is, by using a laser that could determine the sources and sinks of carbon dioxide, all around the planet; all seasons, all latitudes. If we're going to manage the carbon cycle, we've got to have that information. If you give that up, then that's not there.

So, that's why we looked across what we thought was the appropriate suite—we know it's a challenge. We know it's a challenge. And in this budgetary climate, it's a very great challenge. But, the planet is facing very serious issues that are not going to go away. Earthquakes are not going to stop, hurricanes are not going to stop, global warming is not going to stop.

Senator NELSON. What specific actions do you think should be taken to improve the interagency collaboration on Earth Science missions that we seem to have had such difficultly with?

Dr. MOORE. Let me just go back to that from the point that you raised, that we have seen this decline in the NASA budget. And then we had a corresponding increase in the NOAA budget to accomplish the NPOESS and the new GOESS. Now, we have a perfect storm. We lost the money in the NASA budget, and the increase in the NOAA budget did not turn out to give us what we thought we were going to get, so it's kind of a lose-lose situation.

I think that there was a history of NASA essentially doing the R&D side, including the oversight, as we went into an operational sensor. It cost money, but NASA has the talent—the Goddard Space Flight Center, for instance, has the talent to give that kind of independent, tough oversight. I'd like to see us move back to the system that we had in place that brought about the NPOESS program, and the earlier GOESS program. We had trouble back then, but not like today.

Senator NELSON. Anybody else want to jump in on that set of questions? Agency cooperation, collaboration? Dr. Freilich?

STATEMENT OF DR. MICHAEL H. FREILICH, DIRECTOR, EARTH SCIENCE DIVISION, SCIENCE MISSION DIRECTORATE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Dr. FREILICH. Sure.

First, let me say thanks to Dr. Moore, and all of the rest of the people on the Decadal Survey for the thoughtful identification of the science problems, and the guidance that it provides. We welcome the survey, in fact, we asked for it in 2003.

We take the survey's recommendations very, very seriously. In fact, in the Fiscal Year 2008 budget request—that's before you—we are taking care in NASA of all of the precursor missions that were identified in the interim report, as well as the Decadal Survey.

In the next 2 years, we'll be launching five key climate spacecraft, and two more after that, up through 2013. The two later ones are the Landsat Data Continuity Mission (LDCM), and the Global Precipitation Measurement Mission—all of those were highly rated in the Decadal Survey.

So, we take that guidance extremely seriously, and we will be taking the guidance from the Decadal Survey, as the Administration puts together its Fiscal Year 2009 budget, and beyond.

Relative to your question of interagency cooperation—it is a real challenge for this country, and it has been the challenge for some time. It's hard enough to design and implement and fly and validate and exploit the data from first copies of instruments, to then be able to do an interagency transfer, and have those measurements taken reliably on operational spacecraft, so that we can get the 30-year climate data records, which are essential—it's very, very difficult.

In response, I believe to Congressional language in the 2005 Authorization bill, NASA and NOAA are working quite hard together—we have a joint working group specifically focused on research to operations transition. While it is a challenge, and we haven't solved, certainly, all of those problems, or even many of those problems, I think we are strengthening the relationship between those two agencies. I'm new in this job at NASA, but it is certainly one of my very strong objectives, and a high-priority objective, for us to work much more efficiently, much more substantively together.

Senator NELSON. Well, since you are relatively new to this position, I welcome you to get in and try to straighten out some of the problems between NASA and NOAA, and NPOESS includes the Air Force, as well, doesn't it?

When Dr. Griffin was here last week, he questioned whether the Decadal Survey's cost estimates are too optimistic. Is NASA, Dr. Freilich, going to do its own estimates of the recommended missions, and share the results with everybody else?

Dr. FREILICH. Yes. We are embarking on an aggressive series of what we call concept studies, to look very, very carefully at the notional missions that were endorsed, especially the early ones, the highest-priority ones, from the Decadal Survey. The objective of these studies is to use the full costing and engineering analyses machinery of the NASA centers—JPL and Goddard, in particular—to address and understand the technological challenges inherent in getting the measurements that were identified by the Decadal Survey, and the full costs of these missions, including the launch vehicle, and especially, also, the science and the validation.

We're moving aggressively forward on that now, now that we have the Decadal Survey's exact recommendations in terms of the measurements to be taken. When we have those engineering and cost analyses, we will much better be able to generate an integrated road map forward, taking into account the high-priority science that was identified by the Decadal Survey, the issues of NPOESS, and the removal of the climate instruments pursuant to Nunn-McCurdy, that you so eloquently discussed. And the contributions, interest and expertise of our international partners. So, we intend, within the next 12 to 15 months or so, to have an integrated, well-understood, road map forward to make progress. We've done the precursor missions—or I should say, we are finishing the precursor missions, and then we'll be in a position to move forward on the high-priority science that the Decadal Survey guides us toward.

Senator NELSON. And when do you think those cost estimates would be available to the Committee?

Dr. FREILICH. We are working on them now, and we are—as I said, looking carefully at each one of those notional missions, also understanding what we need to do, and can do, to mitigate the NPOESS climate problem. And I think in some months—probably less than 6 months, we will have a fairly clear idea of the true full costs of those notional missions.

Senator NELSON. Dr. Brown, you—OK, I'll get to Ms. Colleton in just a second—Dr. Brown, you've had some excellent testimony about Earth Science satellites, and Ms. Colleton. I want to ask you all about the impact of this research.

STATEMENT OF OTIS D. BROWN, PH.D., DEAN, ROSENSTIEL SCHOOL OF MARINE AND ATMOSPHERIC SCIENCE, UNIVERSITY OF MIAMI; MEMBER, COMMITTEE ON EARTH SCIENCE AND APPLICATIONS FROM SPACE, NATIONAL RESEARCH COUNCIL, THE NATIONAL ACADEMIES

Dr. BROWN. Thank you, Senator.

Let me step back for a minute, and talk about a bit of history here, and it will frame my answer a little better, I think relative to impacts.

The history from the seventies, eighties and nineties, is that each Earth Science community approached NASA individually, and said, "OK, as oceanographers, we need this," "As meteorologists or atmospheric scientists, we need this," "As land-cover, land-use people, we need this," "As climate scientists, we need this." And NASA tried its best in the Earth Observing System to respond in an integrated way to all of these different ideas, requests and needs.

The Decadal Survey was very different, in the sense that, as has happened in astronomy and other disciplines with NASA, NASA asked the community, "You know, you guys are all Earth Scientists, why don't you get together and give us your best set of integrated priorities, rather than us having to decide what the priorities should be of everything you've asked?" That's a fundamental difference, and this downsizing of more than 100 different possibilities to the order of less than 20, is a result of—I wouldn't say smoke-filled rooms, not these days—but, you know, a lot of hard negotiation about saying, "How is it that we can really get the highest priority needs of the broad community on the limited set of missions?"

So, this is a different set of mission requests than anything NASA has ever seen before. But, it had to be built on a base, and this gets into the impacts. The base is what's in space now, the Earth Observing System and a number of other prototype research missions that are flying, things that have to do everything from trying to measure tropical rain rates, to surface vector winds—many different, very unique sorts of missions.

But all of these missions are neither research or operational really. In most cases, they were launched as research missions, but they found operational niches within the government and private industry, not only in this country, but globally.

And so, we're in an interesting situation. How do we sustain these research missions that now have operational needs? Whether it's for trying to better locate a hurricane, or it's trying to better understand issues of drought or rain run-off and floods in tropical regions. All of these results are coming out of, what you would think, looking at the title of the mission, was a research mission, not an operational one.

So, that's a problem. There hasn't been a real functional mechanism to say, "OK, we know it works, now how do we put it into a broader operational context?"

So, one of the zero-order challenges for the Decadal Survey was, what's the foundation you build the future on? That's why—as you look at the high-priority missions, you might get what you think is a bit of a mixed message, because you hear people talking about NPOESS and climate sensors coming off of NPOESS and so on, and in fact, as you look at the projected set of missions from the Decadal Survey, it doesn't really give you a simple answer to that question.

So, let me address the impacts. Impacts, I think, can be direct—operationally now, we're using surface vector winds from various different missions, actually, most all of them research, and in the hurricane community they've been shown to improve forecasts. Case in point—tropical rainfall measuring from space. Again, this is a capability that has had a strong impact.

I think you could say that as you look at the breadth of this whole suite of missions from the mid-nineties to the early part of this millennium, that many of them have been moved into this quasi-operational context. But that context sits between what NASA has traditionally done, and what NOAA does, as its charter.

So that's, why you won't get a totally straightforward answer to your question. I think it's demonstrable what can be done from space, it's demonstrable how long, I think, it'll last, but it's the "Then what?" question. And quite directly, in the Decadal Survey, we had to assume at the outset that NPOESS was going to happen on a certain timescale, with a certain implementation suite, and then go from there.

And, I'd invite the co-chair, if he'd like to comment on this it was a very interesting and detailed, long-term debate within the survey, actually, about how to deal with a moving NPOESS suite of capabilities.

Senator NELSON. Let me ask Ms. Colleton, what do you think?

STATEMENT OF NANCY COLLETON, PRESIDENT, INSTITUTE FOR GLOBAL ENVIRONMENT STRATEGIES; EXECUTIVE DIRECTOR, ALLIANCE FOR EARTH OBSERVATIONS

Ms. COLLETON. I just wanted to make two points, my apologies, thank you.

I just wanted to make two points in reference to the Decadal Survey. The first is that, I think what is most significant about the vision of the Decadal Program that was adopted by this committee that is primarily scientists, is that it went beyond looking just at fundamental science, and it looked at applications for the good of the Nation, and the world. And, I think this is a real much-needed shift as we see more and more private sector entities using this information. We're seeing new developments in our information technologies, that are making this information available to more people than ever before. Think of Google Earth, think of Microsoft Virtual Earth—and those are just the beginning. We will be able to access, and manipulate, and have decision-support tools like never before, in the future certainly.

So, I think it's very important to recognize the essential part of applications. And, I agree with Dr. Brown, totally. When you look at, just for example, the TRIMM mission, the Tropical Rain Measurement mission—that mission is going on its 10th year, I believe. It started out as a research mission, it was—its success criteria was 3 years, it's now in its 10th year. And it's very, very important to our hurricane forecasting. And it was some time ago—I think it was 2 years ago—that there was question as to whether NASA would continue to fund the operation of TRIMM, and NOAA was saying, "But, we need those measurements for the upcoming hurricane season."

And so, there are going to continue to be those kinds of issues, until we have a clear research-to-operations transition plan for the Nation, which brings me to my second point.

I think one of the things that has not been addressed by the Decadal Study that I really believe, as a country, we need to look at—and that's leadership. We recognize more and more how vital these systems are to our livelihood, our property, saving lives, I mean—being from Florida, you know well the importance of hurricane forecasting, and we still, you know, we see the kind of—the fact that we were able to evacuate 90 percent of Southeast Louisiana with 40 hours advance notice with Katrina. That's better than we have ever been able to do.

But, I believe that that transition where this information is no longer just available to the science community, but it's becoming more operational all the time, and we have our economy, is using this information and relying on this information more and more. I think it calls for a new look at how we're doing these programs, and leadership. Without leadership, these programs—the budgets for them—will never be protected. And, there will never be a long-term vision for, as a Nation, for what we should be doing in this area.

Senator NELSON. Dr. Moore?

Dr. MOORE. Yes, let me pick up on that point. And, we had a specific recommendation—I should mention that the recommendation that we initially debated was how to reorganize the Federal Government, and we recognized we must be late in the days of the Committee to be reorganizing the Federal Government.

And so we stepped back from that. And, and yet the motivation was precisely what's being stated—if you look at the way we've, if you will, managed the Earth-observing business in the United States, it has a checkered history.

Now, take Landsat—it's been all over the place—the only place it's not been is the Senate of the United States—it's been in the Air Force, it's been in the U.S. Geological Survey, it went over to NOAA, back to NASA, back over to NOAA, back to NASA—this is observing land surface where people live. This should not be tossed around the Federal Government.

The situation with NPOESS, clearly the lessons will be learned for many painful years. So, what we set forth was the fact that we felt that the Office of Science and Technology Policy has a unique opportunity in the next 2 years, in an Administration which, by definition, will not succeed itself. As far as I know, the Vice President is not running for President. So, you are almost in an apolitical time for OSTP. I'm from New Hampshire, we're not in an apolitical time in New Hampshire—but it is a different scenorio for OSTP to sit down with NASA and NOAA and the U.S. Geological Survey, with the Congress, and with the community and with the private sector, and say, "What could we advise the incoming government in 2008, to do about this Earth observing? Let's see if we can't get this thing on a more rational footing." It is not easy.

I think the primary problem is that the capabilities of agencies do not necessarily line up with their responsibilities. I think that is exactly where we have this problem with NOAA. Their responsibility was for this next-generation weather satellite. But they did not, necessarily have internal capabilities to manage something of that complexity.

So, I believe we're going to have to really rethink the way in which we do business. It's just not working.

Senator NELSON. Dr. Freilich, what about the expected gap between Landsat 7 and the Landsat Data Continuity Mission? What is going to be the scientific impact of that gap?

Dr. FREILICH. I'm not a land scientist myself, in fact, I'm an oceanographer, like Otis Brown here.

However, we have looked, and are continuing to look quite carefully at that. Climate time series are things to be cherished, it takes 30 years to get a 30-year continuous data set. We are investigating with our international partners, what other data sources might be available for the relatively short amount of time between the potential demise of Landsat 7, and the plan for launch and operation of Landsat Data Continuity Mission, which will be in 2011.

There are many, many other countries which are flying, or plan to fly, land-observing missions. Not all of them at the same level of radiometric accuracy, many of them at the same level of spatial resolution, and coverage, as we have. So, we are actively dealing in NASA with our international partners, to try and assemble, as best as possible, a data set of land observations to enable the climate science to continue, and to enable this time series, which we've invested so much in as a Nation, to continue to be able to serve the climate science, as well as other communities.

Senator NELSON. By the way, if we didn't have enough to worry about, the Chinese now have the capability to knock down satellites.

Let me ask Dr. Moore, are the new missions that are currently in NASA's pipeline, such as the Landsat Data Continuity Mission, Glory, and NPP, are they consistent with the Decadal Survey recommendations?

Dr. MOORE. Yes, they are completely consistent.

And, I think that NASA had the interim report, which was released in April of 2005, as a basis to build the 2008 report. The interim budget dealt with the existing programs—Landsat Data Continuity, Glory, so forth, the ones that you've mentioned. And we said, "We really need to get these on track," and the 2008 and 2009 budgets do that.

NASA did not have, in preparation of the 2008 budget, the final report of the Decadal Survey, which looked at the out-years, beyond the existing programs, which the 2008–2009 really address. And as a consequence, if we look at the run-out that, after 2009, things go negative again.

I'm hopeful that Dr. Freilich leadership and with Alan Stern coming in, that in the 2009 budget, we will see that run-out turn around, because the real recommendations of the Decadal Survey deal with these new missions that are the absolute—they are the ones that are dead critical, in terms of the problems that the Decadal Survey was looking at, whether it was earthquakes or climate or severe weather or droughts or greenhouse gases. They're the ones that address those issues.

Senator NELSON. Dr. Brown?

Dr. BROWN. Two answers. One, as Dr. Moore said, the interim report jumpstarted the internal processes within NASA, so that they can address that particular suite of issues, including GPM.

The outstanding problem, though, that is unaddressed—at least from my perspective right now—is the loss of climate sensor capability on NPOESS. We don't have an answer to that problem, in either agency right now.

Senator NELSON. Are any of those projects what you would consider a lower priority?

Dr. BROWN. No. Actually, in terms of the Decadal Survey, no. And as you might imagine, there were a lot of hard negotiations that occurred to come up with that list. And there was a consensus across the panels on the final list, that these really were the -priority missions that needed to be looked at in the next decade. So, I'm on board with those, sir.

Senator NELSON. Well, let me ask to any of you, if the Earth Science Program were to proceed along the current path, which is the bare-bones NPOESS and only the new missions in the NASA pipeline, what are the risks, explain to our Committee, to our Nation's coastal areas?

Dr. BROWN. The risks are multi-fold, some would happen sooner rather than later, Senator. The longer-term risks are, you'll have interruptions of climate quality data records in a number of areas, so you're going to lose continuity and have to restart climate records that you really don't want to lose, which are fundamental to look at long-term changes. For example, there are input solar irradiance versus earth radiation coming out, and understanding aerosol impacts. Those would be areas that could be at risk.

Similarly you could—as you look at some of the other climate-quality instruments on the NPOESS suite, see interruptions in the climate part of the record.

The other part, which is the direct impacts has to do with the slips in NPOESS, what is that going to mean to polar orbiter, visible and infrared mapping coverage of the globe. We don't know that yet, because we don't know what that interval might be. But, if there is some interval, with much-reduced coverage, that's going to undoubtedly have societal impacts, because that's a primary sensor for many different sorts of warnings that might be put out.

An area that I would specifically focus on has to do with, as we look at sea level rise globally, and all of the aspects that go into observing and forecasting it. It includes such esoteric things as trying to map out polar ice extents—and thickness, and so on. Which parts of those capabilities that will be diminished is going to have an impact, as we try to look at sea level rise? It's going to mean errors, the error-bounds or our confidence in estimating these will change, for example. Thank you.

Senator NELSON. Ms. Colleton, what do you think? How's this going to affect ordinary Americans? Not necessarily on the Coast, but if you want to talk about the Coast feel free.

Ms. COLLETON. Well, I think one of the important things that we have to consider is if, if there is a question about our space capability in the future, we have to look at other options. And, we've yet to talk about aircraft and *in situ* measurements, and how important those are. And one of the things that, clearly we're beginning to start is the implementation of the Integrated Ocean Observing System, and all of the regional associations across the country that do coastal monitoring, et cetera. There was money in the President's Fiscal Year 2008 budget to begin that process, I don't think it's enough money, but programs like that will grow in importance, if those space capabilities are not available. And I think they—and the fact that we need to look at more of the integrated information between space, aircraft, and *in situ* information, and develop an integrated Earth Observing System that would have all of those capabilities, is very, very important.

Senator NELSON. Just as an aside, one of the aircraft capabilities of NOAA is the G–4 that flies at 40,000 feet plus, and tracks hurricanes. It's given them a 15 percent greater accuracy in prediction of hurricane paths, with the resulting additional early warning. That's a single-point failure, we don't have a backup aircraft. And I've been trying to beat the door down for the last several years about, "Well, you only need it for 6 months of the year, try to figure out when and where another agency could use it for the other 6 months. You can share it." But, I just spoke to the number two guy at NOAA, and they're not going to. They don't have any plans to come forward and request this. It's just another indication of what you said, Ms. Colleton.

Ms. COLLETON. And, again, I think it elevates the importance of taking a comprehensive look—not just at our space programs, but our U.S. common information infrastructure that we're using, the *in situ* measurements we have, and aircraft. And looking to have someone responsible within our government to look at the whole picture, and determine if it's appropriate or accurate for the challenges that we face.

Dr. MOORE. Senator, could I just elaborate?

Senator NELSON. Please, please.

Dr. MOORE. The question that you asked—if we didn't go ahead with the recommendations of the Decadal Survey, and we are living with the highly reduced NPOESS program, what would be some of the things that you wouldn't have? Well, we wouldn't have good measurements of ice sheets. We know that ice sheets are changing. We know the changes in ice sheets lead to changes in sea level. So, we would not have that.

Second, we wouldn't have good measurements of sea level. One of the missions that we recommend deals with instruments that not only will measure sea level, but will also measure lake levels, as well as major rivers. We wouldn't have that information.

In the GOESS program, they have eliminated the Coastal Waters Imagery. In the Decadal Survey, we recommended a mission that would not only handle coastal waters, but also air pollution, the measurement of air pollution.

So, when you start down the list, I think the coastal communities are living right at the tipping point. And the recommendations that we've made were looking very much at the issue of, what are the applications? Who are the people at risk?

Soil moisture—this is a major issue for coastal areas. There will be far less capability on the NPOESS mission than was planned. One of the missions that we recommended was to directly measure soil moistures.

So, I think that we've tried to identify priorities by looking at these critical populations, and certainly the coastal community is amongst the most critical population, particularly viewed worldwide.

Dr. FREILICH. I would just like to point out that we presently are flying 14 Earth-observing satellites. We've talked a bit about sea level, and that is certainly one of the triumphs—we have accurate measurements of global sea level that started with the TOPEX-Poseidon joint NASA-French Space Agency Program. Presently, the Jason-1 altimetry mission is flying, and the very first of the new missions that are in the budget to launch—and it will launch in 2008—is a yet another follow-on—the Ocean Surface Topography Mission. So, we have focused on very, very high priorities, and ocean surface topography, at least, is one global time series which is going to continue at extremely high accuracy, with good overlap between sensors.

Senator NELSON. Ms. Colleton, how do state and local government use the data from these satellites?

Ms. COLLETON. They use it in a variety of ways. I think probably the best example is in looking at drought, the drought monitor that's available, you know we're experiencing a terrible drought right now in Texas, and last week alone there were terrible dust storms, 35,000 homes and businesses without power, as a result.

But, the satellite data is put into systems, information systems, that allow anyone, anywhere to access it. They can do this through the University of Nebraska at Lincoln, go to the drought monitor and determine what the outlook is, what's currently happening, what the outlook might be for a few weeks ahead.

So it's not only with drought. One of the most exciting things that we're beginning to see in the area of applications is the relationship between environmental information, and public health. And again, it's just an emerging thing. But we can look, for example, at malaria, and look at parts of the world, for example, that may have characteristics that might promote the next malaria outbreak. How is that helpful? Because it helps NGOs get medicine to certain parts of the world, producers to distribute it, et cetera.

One other area that I think will be very, very important with emerging applications of remote sensing, or satellite Earth observations is that we—again, we're just beginning to look at—is the application of this information to the carbon finance market, and how this technology becomes an innovation for climate change. We're looking at renewable fuels, we're looking at emission reductions, but are we looking at Earth observations and how it can be used?

I mean, for one, for example, just in monitoring, it will show us whether or not our policies are working. So, I think for state and local government leaders, this information has a lot of applications.

Senator NELSON. Dr. Freilich, why don't you give us some commentary on why you think NPOESS has had so many problems? What has NASA learned about the structure, so we can apply it to future collaborations?

Dr. FREILICH. An excellent question, Senator.

NPOESS is a step forward from the Earth Observing System that NASA was flying and from the operational weather satellites that NOAA and the Department of Defense separately had been flying, and are flying right now.

In some instances, the instruments that were anticipated to fly, or that were chosen to fly on NPOESS were quite mature, and we had built them, NASA had often demonstrated their capabilities, and their utility, and they transitioned well.

For instance, on the NPOESS Preparatory Project, one of the instruments, the so-called ATMS, Advanced Technology Microwave Sounder instrument, is in good shape. The technology is moving along, it was mature, it is, in fact, already integrated onto the spacecraft.

In some other areas, I think that corporately, we were reaching rather far. We were attempting to get to the next generation of instruments to fly on an operational spacecraft, when perhaps we had not fully examined the technology, and the implementation issues associated with them in the context of research missions. Historically, NASA did the research missions, as you heard previously from my colleagues. Many of our research satellites, virtually all of them, provide data in near-real-time. And, those measurements originally flown for research purposes, when they demonstrate their utility, are then used routinely in operational numerical weather forecasting, marine hazard warning, et cetera.

So, that was the process that we had, and I think that we jumped a little bit, perhaps, in our eagerness to get a truly outstanding operational constellation of instruments. And in my personal opinion, that is not quite the way we had shown it in the past, and the way in which we had experience.

Senator NELSON. Do you think it can meet its revised cost schedule and technical goals?

Dr. FREILICH. NASA is a partner in the NPOESS program as a technology provider. In the short time I've been here, I've not had the time to study the details of where we are in NPOESS as a whole. I think that the Nunn-McCurdy recertification focuses NPOESS on its weather forecasting capabilities, and based on the analyses that went into that, we will be able to achieve those capabilities, that performance.

As far as climate goes, I think that the Nunn–McCurdy re-certification is fairly honest, and it says that, given the resources that are available, we should not be focusing on climate measurements, and therefore, we as a country have to look at how to mitigate the removal of those measurements. It's not that we shouldn't focus on climate, but this program can't afford to focus on climate. We should look to see how to mitigate the impact of removing those sensors, but get the measurements flown in different ways. And, we're actively working with NOAA and other portions of the government through OSTP, in particular to try to come up with mitigation strategies. That will feed into our integrated road map that I talked about previously.

Because, the science and the societal impact that were identified in the Decadal Survey really requires a background context, if you will, of measurements that we had thought were going to be obtained from NPOESS, and if they're not obtained from NPOESS, we still have to make those measurements in order to advance our Earth-system science.

Senator NELSON. Are there particular problems that you think we ought to be on the lookout for?

Dr. FREILICH. Sorry, I don't quite understand the question, whether it's——

Senator NELSON. In the revised cost schedule and technical goals? Do you think we can meet them all, or are there going to be some problems that we ought to be looking for?

Dr. FREILICH. Every space mission that I've been associated with and that I've known about, has had challenges associated with it. There are clearly two instruments on the NPOESS preparatory project—the VIIRS instrument and the CRIS instrument, which at the moment, represent, quite significant technological challenges. They are not NASA-provided instruments, I might point out, but they're critical instruments for the science that has been identified, and for the societal impact that we would like to extract from this national investment.

Senator NELSON. Do you think the NPP will fill the gap between EOS and NPOESS?

Dr. FREILICH. NPP, as well as international partner contributions, in particular, EUMETSAT and the MetOp series of spacecraft, and the instruments and spacecraft that we have in the Fiscal Year 2008 budget will bridge the gap. Those seven missions that I talked about that will launch out between 2008 and 2013 which, by the way, not only includes the Ocean Surface Topography Mission, but also the orbiting carbon observatory that Ms. Colleton talked about, which is also going to launch in 2008. Those missions—and the ones that we're flying now—will certainly not only continue, but expand the range of variables that we're presently measuring, and then the question just becomes a programmatic one, of when the follow-ons take place. Now that we have the clear guidance from the Decadal Survey, we can begin to build those integrated programs.

Senator NELSON. Dr. Moore, you want to talk to us about projects that were dropped from NPOESS, and tell us what you think about the status of them, then Dr. Freilich, why don't you comment on that and to what degree you think you're going to be able to get them in the budget?

Dr. MOORE. Well, there are several. I'll begin with the less expensive ones. Perhaps they could come back into the budget via NOAA. And these are very important for climate.

The total solar irradiance monitor—this monitors the solar output—was dropped. And, the instrument to measure the energy coming off of the planet was dropped. Now, if you're going to do climate work, the concern about climate is the change in the energy balance, because of the greenhouse gases. You've got to have the total solar irradiance, and you've got to have the energy coming off the planet—those are of the first order. The Decadal Survey recommended those back to NOAA because we felt that—not only were they important, but they were not budget breakers. In fact, I think it would probably be in the noise of the uncertainty about the NPOESS budget. So, that would be a very clear recommendation.

The other was the altitude distribution of ozone in the atmosphere. That was eliminated—they were going to continue to measure the total amount of ozone in the column of air, but not see in detail, the altitude. We really need to understand that. So those are three things that we felt could be put back on the NOAA side.

On the other aspects, it appears that there will probably be far less capability of measuring soil moisture. And therefore, one of the early recommendations to NASA was a soil moisture mission. Now, this is a good example of where I think a NASA mission does not fulfill the NOAA and Air Force responsibility. This would be a scientific mission, but there will have to be the capability of taking the data from this scientific mission and incorporating that into the operational side of NOAA and the Air Force.

What worries me, is that in the reduction of the budget for NPOESS, there will be a loss of that capability to utilize that data for operational purposes. So, we're recommending a wide swath altimeter, to look at ocean altimetry, sea level height, as well as rivers and lakes. The altimeter was lost from the NPOESS mission. This is a recommendation to NASA, but once again—will there be the capability of utilizing this data?

Finally, the NPOESS mission was advertised, and still is advertised, as not only a weather mission, but a climate mission—the instruments are said to have climate capability, that means that they're very stable, they make a very precise and accurate measurement.

Well, the NPOESS program has something they call "weather centrals." These are the places that the data is processed for weather prediction purposes. Where's the climate central? In order to produce climate data records, as Mike Freilich said very well, to produce these long time series, they require data that is often reprocessed three, four, five times. The reason for that is, instruments age—(just as we age)—and performance changes. So, as the instrument changes, the algorithms that process the data need to be changed. The algorithms need, for climate signals, to be the very best we can get—not the fastest. For weather purposes, speed is everything. So, where's the climate central? Despite our very clear recommendation in the interim report, and again in the final report, we've never had NOAA respond to that. Yet, if you're going to have a climate mission, you need to produce climate data.

So, first of all, I think there are serious issues with respect to the instruments. Second, we've tried to make a recommendation to NOAA on these energy balance issues—some of the measurements that we've recommended to NASA are high-priority measurements, third, there will still be the cost of ingesting this data, and finally there's the issue of the climate central.

Senator NELSON. What do you think, Dr. Freilich?

Dr. FREILICH. OK, let me go down the list that Dr. Moore presented.

We've already talked about ocean surface topography and altimetry, the OSTM mission will be launching in 2008. Dr. Moore mentioned the radiation balance, and in particular, the total solar irradiance. The Glory mission, which we'll launch at the end of calendar year 2008, is in the final stages of implementation now. It has two instruments on it. One of them is an aerosol polarimetry sensor, but the other is a total solar irradiance sensor. So, that mission is funded, will be launching at the end of 2008, or the very beginning of 2009—and that will continue that extremely important time series. Which, by the way, requires absolute overlap of the measurements. We, unfortunately are not in a position where we can build total solar irradiance instruments which have sufficiently good absolute accuracy to tolerate a gap. But, we have a TSI, a Total Solar Irradiance instrument, which will launch on the Glory mission, and that one is good.

As far as the Earth Radiation budget instrumentation, the CLARREO mission, as Dr. Moore pointed out, is a joint set of measurements between NASA and NOAA. It is one of the potentially lower cost missions, we're looking at it carefully, and certainly one of the high-priority science ones, and we'll be looking very carefully—it's one of the four earliest missions that the Decadal Survey recommended, and we'll be looking very carefully and be guided by the Decadal Survey, as I've said many times, in putting together our integrated plan. So, it's going to be quite high up, in our focus early on.

Senator NELSON. And what year do you think that will come in?

Dr. FREILICH. I can't say right now, because we have to put the plan together, and it has to account—as I said before—for all of the measurements that are required to advance the science. We need to be able to balance the resources that are available with all of the measurements that we need, including the new measurements for the Decadal Survey science, such as soil moisture, and the context measurements that would have been provided by NPOESS, had it gone as expected. So, as in so many other things that we do—and as is emphasized so strongly in the Decadal Survey, where they talk about balance between disciplines, and balance between research and flight projects, and balance between airborne and *in situ* measurements—we have to deal with balance for the Nation, certainly, for NASA, and inside the Earth Science Division. But that's the whole point of our integrated roadmap, which we are embarked on right now, given the clear objectives that have been set out by the Decadal Survey.

I might also point out, sir, if I can, that the Fiscal Year 2008 President's budget requests funding for a mission—a competitively selected, unspecified Earth Systems Science Pathfinder mission—that is a medium-sized mission and will launch in approximately 2014. As part of our integrated roadmap, we are taking that line into account. So, I think that, an answer to your question is that, when we put the integrated roadmap together, there is money in the President's budget for a medium-sized mission to launch in 2014, and the question is, precisely what scientific focus should it have?

Senator NELSON. Would it consider the other two that were left off, for the measurement of the soil moisture and for the altitude distribution of ozone?

Dr. FREILICH. Let me deal with them separately. The altitude distribution of ozone is a relatively small and relatively mature technology that we have. In fact, the total ozone and the atmospheric profile were supposed to be two instruments originally, but that were closely linked to each other, and we will look very, very carefully at getting that one flown rapidly.

That is not in the same class of investment technology, or anything else that we're talking about for the other ones.

In terms of soil moisture, there are a number of possibilities that were laid out in the Decadal Survey and they dovetail, actually, fairly well in some cases with the Global Precipitation Measurement Mission. And we're looking carefully, as I keep saying, at an integrated approach to make the best use of the resources that we have—so that if we can, in fact, overlap some of these and kill multiple birds with fewer stones, we're looking very, very, carefully at doing that.

NASA's contributions to the Global Precipitation Mission has two parts to it. The first is a core spacecraft, joint with our Japanese Space Agency partners, that will have a couple of different instruments on it—an active precipitation radar, and a passive radiometer. That will launch in 2013. In 2014, however, this budget line includes the so-called GPM Constellation spacecraft, which we need in order to get the good, accurate global precipitation measurements, that GPM as a unit, is intended to provide.

However, the radiometer that is on that spacecraft may, perhaps, be able to be adapted, enhanced, whatever—I don't want to do design in front of the Senate, in fact, I'm not even capable of doing design in my office, being an oceanographer. However, those are the sorts of questions that we're asking ourselves, as we put together the integrated roadmap—how best to get the measurements that we need that advance the science with the resources that we have available.

Senator NELSON. And what about the idea of weather centrals becoming climate centrals, as Ms. Colleton mentioned?

Dr. FREILICH. I'm not sure that I heard that weather centrals should become climate centrals, what I heard Ms. Colleton and Dr. Moore say, was that capability, that function, must be recognized as scientifically and societally very important. NASA, in general, does not do that sort of work, because that's an operational kind of capability. However, we really, really need it in order to advance both the science and the societal impact.

Senator NELSON. Ms. Colleton, do you want to expand on that?

Ms. COLLETON. I think that Dr. Moore said it appropriately.

Senator NELSON. Turn on your mike.

Ms. COLLETON. Sorry—I'll learn by the time this hearing is over, to turn on my microphone, I apologize.

But, I think Dr. Moore said it accurately—the way that the NPOESS program is structured right now, there is this focus on weather centrals, that rely and push for speed in delivery, where the climate centrals aren't being considered at this point, and those require more sensitive types of instrumentation, and processing.

Is that correct, Dr. Moore?

Dr. MOORE. I think that, the weather centrals have their job, and it's best to let them focus on that job. A climate central needs a different oversight, a different scientific oversight, it requires advanced computing—as does the weather—but perhaps it should be structured differently, and separated from the task of the weather centrals.

Our concern is that, right now, it's not in the budget, it doesn't appear to be in the planning, speaking to NOAA, and I do not see any way to simply try to piggy-back it on something else. I think it's a very serious enterprise, and it's not being addressed.

The other comment I wanted to make was when I addressed the issue on the solar monitoring and so forth—I was taking into consideration that NASA on the Glory mission gets us to about 2013 with this solar monitoring. But then it stops, because it's deleted from the NPOESS mission. So, our recommendation is that, it's not expensive, it is highly important, as Mike said, you've got to have it overlap with whatever is on-orbit at that time, making that measurement, because you need to get a consistent time series. And therefore, it was natural to put it on, put it back on the first NPOESS spacecraft.

But, it requires resources. And what I'm afraid of is, the NPOESS situation is not in closure yet, and we may see additional pressure on the program, and therefore there will not be the ability to respond to these very real needs that we're going to have. And I just don't see how they're going to be met, unless things change.

Dr. BROWN. Senator, a final comment from me on that. Let's, and, go back to the earlier discussion that we had on the Decadal Survey committee. And that was that, you know, should you restructure the Federal Government to deal with these challenges of the NPOESS program?

What you see, though, is when restructuring had to happen because of Nunn-McCurdy, there was no climate sponsor to step up and say, "That's my responsibility I want to preserve that. Here's a budget to do that." That, I think, is a fundamental issue as we move into this new suite of satellites. Who is going to be the climate sponsor for Earth Observing Systems? I don't know what the answer is. I'm not going to presume that, but I do think that is the question.

Senator NELSON. Any further comments from any of you all? Yes, ma'am?

Ms. COLLETON. If I could, we've spent a lot of time talking about NPOESS this afternoon. But I think, again, we have to consider, NPOESS is supposed to go through 2024, and are we considering what follows? Or, are some of these missions that are getting set back longer and longer times. Again, I would call—I would hope that you would call—for a long-term strategy for Earth observations. We do not have one. We do not have a national strategy, we need to address these climate questions, it's imperative, and I would hope that you would call for such an action.

Senator NELSON. Dr. Moore, you were about to say something?

Dr. MOORE. Yes, one final comment—I recognize that when we put forth 17 missions, and say we need to get back to the year 2000, that's a major step. We could have classed those missions, grouped them into three large spacecraft, and said we're only recommending three missions. We thought we were recommending a more robust strategy by breaking it up.

So, let's think about how we might exploit that robust strategy. Mike Freilich has spoken, I think, very positively, we all appreciate it in the community—about the Decadal Survey. Let's see if we can't find a way to actually embrace it, beyond these road-mapping exercises. And so, what I would like to suggest is, we've recommended 17 missions to NASA. Let's look at the first six or seven of them. Let's start with them. Say, $10 million a year for seven missions to do the kind of detailed cost analysis, do the kind of detailed high technological risk parts, the so-called “tall poles”—let’s start working those right now.

So, $70 million to take on the first seven—what would happen? Well, first of all, we would all join forces in the community because we would see a positive response. The country, I think, would begin to feel positively too, that we’ve got this thing back on track. Industry would look at this and say, “Well, Earth Science is a place that we need to put our industrial money.” I know the industry, quite often will say, “Well, if NASA’s going to invest “X” number of dollars, we need to invest that, because we’re competing against our peers out here.” So, when you’re in a hole, the first thing you do is stop digging. Instead we would start to dig steps out of the hole. So, by making that kind of investment—$70 million is a lot of money, but in other ways, it’s not a lot of money.

Senator NELSON. Anything from you all for the record?

Dr. FREILICH. Thank you very much.

Senator NELSON. Well, thank you for your time. I did not introduce you all, we just started right in on our conversation. Dr. Freilich is the Director of the Earth Sciences Division of the Science Mission Directorate at NASA, Dr. Moore is Director of the Institute for Study of Earth, Oceans, and Space at the University of New Hampshire, Dr. Brown is the Dean of the Rosenstiel School of Marine and Atmospheric Science at the University of Miami, and Ms. Colleton is the President of the Institute for Global Environmental Strategies, and is the Executive Director for the Alliance for Earth Observations. So, you all have added mightily to our knowledge, and our attempts to try to get this right. So, thank you very much.

The meeting is adjourned.

[Whereupon, at 4 p.m., the hearing was adjourned.]

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